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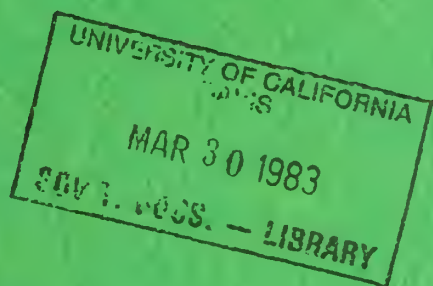
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LOPE STABILITY AND GEOLOGY OF THE BALDWIN HILLS, S ANGELES COUNTY, CALIFORNIA

1982

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY



SPECIAL REPORT 152

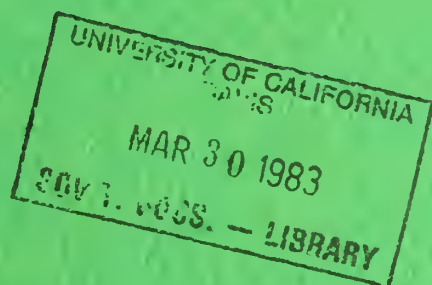


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SLOPE STABILITY AND GEOLOGY
OF THE BALDWIN HILLS,
LOS ANGELES COUNTY, CALIFORNIA

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SPECIAL REPORT 152



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STATE GEOLOGIST

SPECIAL REPORT 152

SLOPE STABILITY AND GEOLOGY OF
THE BALDWIN HILLS,
LOS ANGELES COUNTY, CALIFORNIA

This study was mandated by Assembly Bill 1571,
authored by Assemblywoman Gwen Moore.

1982

By

California Division of Mines and Geology Staff

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Note: This report supersedes California Division of Mines and
Geology Open File Report OFR 80-14, Slope Stability
Study of the Baldwin Hills, Los Angeles County, Cali-
fornia.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

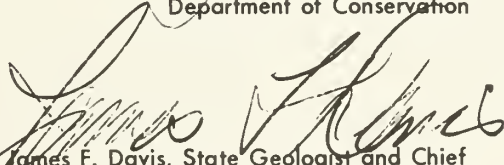
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FOREWORD

The Baldwin Hills area is not unique in having a serious slope failure problem. The problem is common to many highly populated or developing areas of coastal California. While many of these areas share certain conditions that are basic to the problem (steep slopes and a potential for heavy seasonal rains), each area has its own unique complexes of conditions that must be understood in order to deal effectively with the problem. For this reason we strongly suggest that measures be taken to ensure that all of these areas are provided with the kind of in-depth understanding and detailed recommendations for mitigation of the problem that this report provides for the Baldwin Hills. This kind of area-specific study, based upon sound geologic investigation, is the best insurance that effective mitigative measures, for application both before urbanization and after, are identified. There is a need to develop new State and local policies to provide enhanced hazard reduction capabilities.



Jan Denton, Director
Department of Conservation



James F. Davis, State Geologist and Chief
Division of Mines and Geology



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CONTENTS

	Page
FOREWORD	iii
ABSTRACT	ix
SUMMARY OF RECOMMENDATIONS FOR STABILIZING SLOPES IN THE BALDWIN HILLS	x
INTRODUCTION	1
Legislative Mandate for Study.....	1
Acknowledgments	1
URBAN SETTING OF THE SLOPE STABILITY PROBLEMS OF THE BALDWIN HILLS.....	2
FACTORS THAT RELATE TO SLOPE INSTABILITY AND FAILURE IN THE BALDWIN HILLS	4
Geologic setting and Topography (By F.H. Weber, Jr.)	4
Rainfall (By F.H. Weber, Jr.)	5
Rock units (By E.Y. Hsu, R.B. Saul, and F.H. Weber, Jr.)	8
Inglewood Formation (Qi)	8
Culver sand (Qc)	10
Baldwin Hills sandy gravel (Qb)	10
Fox Hills relict paleosol (Qf)	11
Pre-development landslides (Qls)	11
Older alluvium (Qfpu)	22
Younger colluvium and alluvium (Qco, Qfp, Qfpm)	22
Artificial fill (of)	23
Geologic history (By R.B. Saul and F.H. Weber, Jr.)	23
Introduction	23
Early Pleistocene (2 to 1 million years ago or less)	23
Late Pleistocene (1 million years or less to 10,000 years ago)	24
Holocene (10,000 years ago to present)	26
Development of grading codes (By E.Y. Hsu)	27
Introduction	27
Pre-1952	28
1952-1963	29
1963-1980	30
GENERAL FEATURES OF SLOPE FAILURE AND ADDITIONAL GEOLOGIC HAZARDS	
IN THE BALDWIN HILLS (By F.H. Weber, Jr.)	30
Landslides and erosion	30
Fill settlement	31
Seismic hazards, including potential for slope failure and fill settlement caused by ground shaking	31
Recent surface movements	33
DETAILED DESCRIPTION AND EVALUATION OF DAMAGING SLOPE FAILURES THAT HAVE OCCURRED IN THE BALDWIN HILLS IN 1978, 1980, AND OTHER YEARS.....	35
Introduction	35
Sub-Area 1: Northwestern Area (Culver City 90230 and Los Angeles City and County 90016) (Slope failure localities 1-8) (By J.A. Treiman)	35
Introduction and summary.....	35
Slope segments 1A through 1H	35
Sub-Area 2: North-Central Area (Los Angeles City and County 90008) (Slope failure localities 9-51) (By J.A. Treiman)	38
Introduction and summary.....	38
Slope segments 2A through 2V	38
Sub-Area 3: Northeastern Area (Los Angeles City 90008 and north edge of View Park - Windsor Hills, Los Angeles County, 90043) (Slope failure localities 52-81) (By E.Y. Hsu and S.S. Ton)	47
Introduction	47
Slope segments 3A through 3X	47
Summary of causes of slope failure	55
Sub-Area 4: Southwestern Area (Culver City 90230) (Slope failure localities 82-89) (By E.Y. Hsu and S.S. Ton)	57
Introduction	57
Development methods	57
Slope segments 4A through 4J	57
Causes and evolution of slope failures	59

	Page
Sub-Area 5: Central Area (Principally Inglewood Oil Field, Los Angeles County) (Slope failure localities 90-92) (By R.B. Saul and F.H. Weber, Jr.)	59
Sub-Area 6: Southern and Southeastern Areas (View Park, Windsor Hills, and Ladera Heights, Los Angeles County 90043 and 90056) (Slope failure localities 93-98) (By E.Y. Hsu, S.S. Tan, and F.H. Weber, Jr.)	63
GENERAL EVALUATION OF THE PROBLEMS OF SLOPE FAILURE IN THE BALDWIN HILLS AND RECOMMENDATIONS FOR THE STABILIZATION OF SLOPES	
(By E.Y. Hsu, S.S. Tan, J.A. Treiman, and F.H. Weber, Jr. in alphabetical order)	64
Introduction.....	64
General Evaluation of the Causes of Slope Failure	64
Recognition of Potential Problems	64
Reconstruction of Slopes and Accompanying Retaining Walls and Drainage Devices That Have Failed	64
Slope repair.....	64
Application of engineered fill	64
Slope surface covers	66
Slope flattening	70
Construction of revetment systems	70
Retaining walls	71
Drainage devices.....	72
Vegetation cover	73
Modification of Slopes That Have Not Failed in Order to Reduce the Hazard of Their Possible Failure	73
Control of moisture infiltration and runoff	73
Chemical stabilization	74
Slope flattening.....	75
Emplacement of slope and deflection walls and debris fences	75
Additional Considerations.....	75
Gully erosion control.....	75
Fill stabilization	76
Slope Maintenance.....	76
General Conclusions	77
REFERENCES CITED (including pamphlets prepared for property owners as guides to planting and maintaining slopes)	79
APPENDICES	
I. Assembly Bill 1571	82
II. Residential and Commercial Properties in the Baldwin Hills Damaged by the Effects of Rainfall in 1969, 1978, and 1980.....	84
III. Glossary of Selected Terms Used in This Report	87
IV. Aerial Photography Utilized in This Study	90
V. Credits for Tables, Plate I, Figures, and Photos.....	91
VI. Description of "Geologic Hazard Abatement Districts".....	91
VII. Participation in This Project by Division of Mines and Geology and Department of Conservation Staff, and Curriculum Vitae for Principal Investigators	92
VIII. Explanation of Preparation of Aerial Geology Portion of Plate I.....	93

Tables

Table 1. Descriptions of rock units	14
Table 2. Soil test data for Sub-areas 1 - 4*	17
Table 3a. Descriptions of slope failures in the northwestern area of the Baldwin Hills (Sub-area 1) **	Plate 2
Table 3b. Descriptions of slope failures in the north-central area of the Baldwin Hills (Sub-area 2) **	Plate 2
Table 3c. Descriptions of slope failures in the northeastern area of the Baldwin Hills (Sub-area 3) **	Plate 2
Table 3d. Descriptions of slope failures in the southwestern area of the Baldwin Hills (Sub-area 4) **	Plate 2
Table 4. Number of residential properties damaged in Sub-areas 2-4, compared to total number of residential properties in these Sub-areas	77

*Localities for sample localities are shown on Plate I. **Localities for these descriptions are shown on Plate I.

ILLUSTRATIONS

Figures

	Page
Figure 1. Southern California coastal region showing study area and faults	2
Figure 2. Western Los Angeles area showing study area and portion of Newport-Inglewood zone of faults and folds	3
Figure 3. Topographic map of study area showing individual sub-areas of study and boundaries between governmental jurisdictions: County of Los Angeles, City of Los Angeles, and Culver City	3
Figure 4. Pre-development topographic map showing steep topography in the north part of the Baldwin Hills	4
Figure 5. Simplified schematic cross section showing topographic and geologic relationships of the study area	5
Figure 6a. Graph of rainfall, 1968-69	9
Figure 6b. Graph of rainfall, 1977-78	9
Figure 6c. Graph of rainfall, 1979-80	10
Figure 7a. Possible, probable, and well-identified bedrock landslides in the north part of the Baldwin Hills plotted on 1926 topographic map	12
Figure 7b. Possible, probable, and well-identified bedrock landslides in the north part of the Baldwin Hills plotted on modern topographic map	12
Figure 8. Block diagram illustrating geologic history	24
Figure 9. Pictorial diagrams illustrating geologic history	25
Figure 10. Topographic map showing marshy ground and other features of the study area in 1901	27
Figure 11. Fault rupture hazard zones in the Baldwin Hills (from Special Studies Zones Maps of Beverly Hills, Hollywood, and Inglewood quadrangles)	32
Figure 12. Map showing sub-areas investigated	36
Figure 13. Typical slope conditions in residential areas of the Baldwin Hills as graded during tract development	65
Figure 14. Diagrammatic cross section showing typical hillside conditions in the Baldwin Hills that lead to slope failure	65
Figure 15. Diagrammatic block diagram illustrating preventive measures that can be taken to alleviate slope instability	67
Figure 16. Diagrammatic cross section illustrating use of engineered fill to stabilize slopes	67
Figure 17. Diagrammatic cross section illustrating use of a revetment system to stabilize slopes	68
Figure 18. Diagrammatic cross section illustrating use of a combination of engineered fill and a revetment system to stabilize slopes	71
Figure 19. Map showing general landslide propensity of the Baldwin Hills	78

Photos

Photo 1. Aerial view west in 1939.....	6
Photo 2. Aerial view west in 1936 showing ancient bedrock landslides	6
Photo 3. Vertical aerial view in 1941 showing ancient bedrock landslides.....	7
Photo 4. Aerial view westerly in 1932 showing incised drainages (denoting accelerated erosion) in largely undeveloped terrain	8
Photo 5. Eroded Culver sand	11
Photo 6. Resistant Fox Hills relict paleosol.....	13
Photo 7. Aerial view south in 1936 showing ancient bedrock landslides.....	13
Photo 8. Aerial view south probably in the early 1940s showing possible bedrock landslides in Cloverdale Avenue area	16
Photo 9. Contact between Culver sand and Baldwin Hills sandy gravel	26
Photo 10. Aerial view northwesterly in 1951 showing development underway near Stacker Street and Don Felipe Drive	28
Photo 11. Aerial view south in 1952 showing development near La Cienega Boulevard	29
Photo 12. Damage in Inglewood caused by 1920 earthquake	32
Photo 13. Aerial view north showing destruction downstream caused by failure of Baldwin Hills Reservoir dam in 1963	34

	Page
Phata 14. Damaging bedrock landslide on south side of Jefferson Boulevard	37
Phata 15. Damaging fill settlement in Culver City	38
Phata 16. Aerial view easterly across La Cienega Boulevard	40
Phata 17. Slope failures in natural terrain south of Carmona Avenue	41
Phata 18. Damaging slope failures on east side of Cloverdale Avenue	44
Photo 19. Aerial view showing slopes along Mantova Drive damaged by rains in 1978	45
Phata 20. Aerial view northwest showing slope adjoining Mantova and Punta Alta Drives that was damaged by rains in 1978.....	46
Phata 21. Closeup aerial view of slope failures in vicinity of Don Alegre Place, Dan Milagra Drive, and Dan Rudolfo Place	48
Phata 22. Damaging debris flow between Dan Alegre Place and Hillcrest Drive.....	50
Phata 23. Damaging shallow slump in vicinity of Dan Mariana Drive	51
Phata 24. Aerial view of slope failures in the vicinity of Stacker Street.....	52
Phata 25. Closeup aerial view of slope damage in the vicinity of Stacker Street	53
Photo 26. Closeup ground view showing steepness of damaged slope in the vicinity of Stacker Street.....	54
Photo 27. Closeup aerial view of slope damage in the vicinity of Stacker Street	56
Phata 28. Damaging debris slides and flaws on Tellefsan Road	58
Phata 29. Slope in Photo 28, as repaired	58
Phata 30. Erosion along a dirt bike trail	60
Photo 31. Gully in a dirt bike trail	61
Photo 32. Deep gully along a roadway.....	62
Phata 33. Effects of "piping"	63
Phata 34. A reconstructed slope on Crestview Road	66
Phata 35. Repaired slope damage on Cloverdale Avenue.....	68
Photo 36. Example of use of gunite and board and pipe revetment structures to repair slope adjoining Dan Milagra Drive	69
Phata 37. Example of building blocks used to protect slopes	69
Phata 38. Expedient use of pipe and board revetment structures to repair slope adjoining Cloverdale Avenue	70
Phata 39. Use of board and pipe revetment structures and slope-retaining wall to repair slope adjoining Dan Tamasa Drive	72
Phata 40. Retaining wall under construction to repair upper part of slope on south side of Stacker Street.....	73
Phata 41. "Swiss cheese" effect caused by pervasive digging of gophers	74
Phata 42. Gopher holes in newly graded slope	75
Photo 43. Closeup view of gopher holes in Photo 42	76

Plates

Plate 1. Geologic map of the Baldwin Hills, Los Angeles County, California, showing slope failures caused by rainfall in 1978 and other years, and additional factors relating to the stabilization of slopes	In pocket
Plate 2. Descriptions of Slope failures I-89, in Sub-areas I-4 (Tables 3a - d)	In pocket

ABSTRACT

Residential tracts of the Baldwin Hills have suffered widespread damage from slope failures caused by torrential rains in 1969, 1978, and 1980. Less widespread failures have occurred in other years. Most of these failures have taken place in the northern part of the hills, between La Cienega Boulevard and Stacker Street, in the City of Los Angeles, but they have also occurred in the western part of the hills which comprises part of Culver City and an unincorporated part of the County of Los Angeles.

The problems of slope instability are particularly severe in the Baldwin Hills for two reasons. First, the hills were mostly developed in the very late 1940s and the 1950s, prior to enactment of stringent grading codes by local governments. Second, the terrain developed consisted mostly of steep natural slopes underlain by soft sedimentary rocks. The resulting tracts contain graded and natural slopes with angles as steep as 45° (1:1), or even steeper, commonly without proper drainage devices and retaining walls. (Modern grading codes require that cut and fill slopes be designed no steeper than 26 1/2° [2:1], unless steeper angles can be shown to be stable.) Additionally, fills were not emplaced as effectively as they would have been under today's more stringent compaction and supervision requirements.

The present study was mandated by Assembly Bill 1571, which was introduced in the State Assembly on March 29, 1979 by Assemblywoman Gwen Maare, of the 49th District (which includes the Baldwin Hills) and signed into law by Governor Edmund G. Brown Jr. on March 11, 1980. This law specifies that the Division of Mines and Geology is to identify the nature and cause of the slope failures and to provide this information to local governments within whose jurisdictions the failures occurred so that they can plan action to mitigate the problems caused by the failures. The Act appropriated the sum of \$85,000 from the State's General Fund for the Division to carry out the study. Findings were to be reported within six months.

In the ensuing study, slope failures in the principal areas of damage caused by the rains were mapped in great detail by California Division of Mines and Geology staff. The initial findings of the study were reported in an open file report (OFR 80-14) that includes a map depicting principal slope failures at a scale of 1 inch equals 400 feet. The text of this initial report describes the principal slope failures and recommends techniques for stabilizing the damaged slopes as well as those undamaged slopes that have an apparent potential for future failure. The initial report also includes maps depicting areal geology and showing individual properties damaged. In this, the final report for the study, maps depicting slope failures, areal geology, and properties damaged have been combined onto a single plate; additionally, segments of individual slopes or slope complexes along with related problems are outlined on the plate. Problems and possible mitigating measures are discussed in the text.

Slope failures in the Baldwin Hills have occurred in the form of landslides and erosion, associated with unusually heavy winter rainfall. The landslides have consisted principally of surficial debris slides ("mudslides," including soil slips) and debris flows ("mudflows"). These failures are derived partly from the mantle of soil and slope wash that overlies the bedrock of natural slopes and partly from weathered bedrock and fill. Slopes underlain by the Inglewood Formation are particularly vulnerable to surficial slides and flows because the surficial mantle developed on bedrock of this formation contains abundant clay material. Deep-seated landsliding as a cause of damage has been uncommon, although during this study apparent large, ancient landslides, previously unrecognized, were mapped. Erosion has consisted of rilling and gullying that commonly has occurred in slopes where the surficial mantle has been stripped away by surficial landsliding. Slopes underlain by the Culver sand are particularly vulnerable to erosion. Most of the slope failures mapped have damaged more than one property.

In just the City of Los Angeles portion of the Baldwin Hills, rains in 1978 caused roughly \$1.450 million damage to about 275 residential properties, an average of about \$5,200 damage to each property. In the three most densely developed areas of the hills that have suffered slope damage in the past, 345 (about 21%) of 1668 residential properties are known by California Division of Mines and Geology staff to have been damaged by slope failure. Additionally, about 93% of the 1668 residential properties apparently have been the potential for at least minor damage from slope failure in the future unless measures are taken to stabilize permanently slopes that include or endanger these properties.

SUMMARY OF RECOMMENDATIONS FOR STABILIZING SLOPES IN THE BALDWIN HILLS

Controlling the impact and runoff of rainfall and the penetration of rain and irrigation water into the ground are basic in the effort to stabilize slopes. To control the impact of rainfall, an effective vegetation cover is important. To give strength to slopes, deep rooted, drought-resistant plants that require only a minimum of irrigation should be planted. Additionally, and very importantly, it is necessary to control the digging and burrowing of gophers and other animals on an area-wide basis in order to reduce deterioration of slopes and to prevent infiltration of water runoff during rainfall.

To prevent landsliding and erosion during runoff of rainfall, diversion structures should be placed on slopes: these include terraced bench drains to collect the water, and surface and sub-surface drains to remove it to streets and flood control structures. At the tops of slopes, retaining walls and berms should be constructed to support fills and to prevent water from flowing over the rear edges of backyards and down slopes. Also, water should not be allowed to pond in backyards and seep into the ground; this is a principal cause of fill settlement. At the bottoms of slopes, retaining and slough walls should be constructed with sufficient freeboard above slope surfaces to give support to steep slopes and to protect backyards and buildings against possible debris flows and slides that originate up slope. Board and pipe revetment systems and engineered fill (including soil cement) can also be used effectively to stabilize slopes in the Baldwin Hills. (Many board and pipe revetment systems that were constructed in the Baldwin Hills after the 1978 rains, however, were not sufficiently effective to prevent slope failures during the 1980 rains.)

Most damaged slopes in the Baldwin Hills include more than one property—commonly 5 to 10 or more. Many more properties are threatened by undamaged but unstable portions of a slope that are adjacent to damaged portions. It is thus imperative that the expensive permanent mitigating measures required to repair and stabilize slopes be done on a cooperative basis among property owners and local, State and Federal governments. An effective method for cooperatively stabilizing slopes made possible by recent State legislation is to establish one or more "geological hazard abatement districts" in the Baldwin Hills. Such districts constitute an efficient and economical means of guaranteeing that slopes affecting multiple properties will be properly stabilized and maintained, even when the ownership of individual properties changes.

SLOPE STABILITY AND GEOLOGY OF THE BALDWIN HILLS, LOS ANGELES COUNTY, CALIFORNIA

INTRODUCTION

Legislative Mandate for Study

This study of slope stability problems of the Baldwin Hills was mandated by Assembly Bill (A.B.) 1571, which was introduced in the State Assembly by Assemblywoman Gwen Moore on March 29, 1979. The study area is within Assemblywoman Moore's 49th District, which stretches from Marina del Rey eastward to south-central Los Angeles. The bill, as amended, passed the Assembly on August 23, 1979 and the Senate on March 6, 1980. It was signed into law by Governor Edmund G. Brown Jr. on March 11, 1980, and, because it was given an "urgency" clause (Section 5), its enactment went into effect the next day, March 12. (The entire Act is reproduced herein as Appendix I.)

The Act has two basic provisions. First, it adds Section 5105 to the Streets and Highways Code, pertaining to the Improvement Act of 1911; this latter act authorizes local governments to create assessment districts for paying for improvements. Section 5105, as summarized by the Legislative Analyst, authorizes (under basic provisions of the 1911 Act) work to mitigate, abate or control a geologic hazard, or work to repair damages therefrom; Section 5105 also authorizes the performance of such work on private property under specified conditions. Second, the Act mandates that

The Division of Mines and Geology of the Department of Conservation shall carry out a study of slope stability problems associated with excessive rainfall in 1978 in the City of Los Angeles and the County of Los Angeles in the Baldwin Hills area, including portions of the communities of Culver City, View Park, and Windsor Hills.

The study shall identify the principal types of slope stability damage and the principal geologic factors that caused that damage. The study shall provide recommendations to enable local officials to determine appropriate site-specific engineering and stabilization measures and costs to mitigate landslide hazards in the area.

The Act appropriated the sum of \$85,000 from the State's General Fund for the Division of Mines and Geology to carry out the study. The Division was ordered to report its findings within six months after the effective date of the Act to the Governor, the Legislature, the Board of Supervisors of the County of Los Angeles, and the City Council of the City of Los

Angeles. These findings were reported in an open-file report (California Division of Mines and Geology staff, 1980). The Act also provides that if an assessment district is formed by local governments to stabilize damaged and endangered slopes in the study area, the \$85,000 would be repaid with interest by the district to the State.

Acknowledgments

Special thanks go first to the residents of the Baldwin Hills for their cooperation during the field investigation for this study. In addition, officials of local government agencies were very generous with their assistance in making available reports and data from their files. These include Larry W. Westphal, Senior Structural Engineering Associate of the Los Angeles City Department of Building and Safety; Clyde E. Easterly and George Stolt of the Street Opening and Widening Division, Bureau of Engineering, Los Angeles City Department of Public Works; Orville E. McCollom, Supervising Regional Engineer of the Los Angeles County Department of County Engineer-Facilities; John Lathrop, City Engineer of Culver City and staff members of the Building and Engineering Divisions; and S. Henry Mayeda, engineering geologist for the Los Angeles City Department of Water and Power. Arthur Keene, geologist for the Department of Los Angeles County Engineer, furnished a report that his staff had made of slope damage in 1978 in the Los Angeles County part of the Baldwin Hills.

Author C. Fong and Steven L. Stockton of the U.S. Corps of Engineers, Soil Engineering section, Foundations and Materials Branch, Portland, Oregon, made available data and aerial photographs from the preliminary phases of a study by the Corps of Engineers of flood and debris flow control involving the Baldwin Hills area and Ballona Creek channel. Also, the Division of Mines and Geology wishes to thank officials of Chevron, Shell, and Getty oil companies for their cooperation with regard to access to oil field property during the field investigation. Robert C. Erickson, of Chevron U.S.A., Inc., furnished information on the geology of the Baldwin Hills and its environs.

The initial version of this report was reviewed carefully and helpfully by Joseph Cobarrubias, geologist for the Los Angeles City Department of Building and Safety, and by John T. McGill, Engineering Geology Branch of the U.S. Geological Survey. The suggestions of both Cobarrubias and McGill were very helpful.

Finally, the staff of the Division of Mines and Geology wishes to thank Assemblywoman Gwen Moore and the staff of her Los Angeles field office, Joy Atkinson, Linda Wormely, and Kenneth Fry, for their many courtesies during the course of the project.

URBAN SETTING OF SLOPE STABILITY PROBLEMS OF THE BALDWIN HILLS

The Baldwin Hills, named after E.J. "Lucky" Baldwin, who once owned part of the hills before they were developed, lie within the Los Angeles Basin about nine miles southwest of Los Angeles Civic Center and five miles northeast of Marina del Rey (Figures 1 and 2). The study area, which includes only the more northern and steepest part of the Baldwin Hills, encompasses about six square miles of the hills. This area is roughly rectangular in shape: it is bounded on the west by Jefferson Boulevard, on the north by Jefferson Boulevard, Coliseum Street, and other streets, on the east by Crenshaw Boulevard, and on the south by Slauson Avenue (Figure 3).

The study area includes parts of three local governmental jurisdictions, which are joined together in a rather complicated, jigsaw puzzle-like pattern (Figure 3). These jurisdictions are the County of Los Angeles, the City of Los Angeles, and the City of Culver City. The City of Inglewood borders the study area to the south.

Only about one-fifth (roughly 1.2 square miles) of the northern part of the Baldwin Hills is included within the City of Los

Angeles, but much of this small area is intensely developed with tracts of single family residences and a lesser number of multiple living-unit buildings, and it is the part of the hills with most of the steepest slopes. By far the greatest amount of damage caused by slope failure in 1978 and in other years has occurred in the City of Los Angeles portion of the hills (mostly Sub-areas 2 and 3, Figure 3).

The largest portion of the northern part of the Baldwin Hills, about 4 square miles, is an unincorporated part of the County of Los Angeles. The northwest-central half of this area is covered by the Inglewood oil field (Sub-area 5, Figure 3); the south-southeast half by populated areas, including View Park, Windsor Hills, and the north part of the community of Ladera Heights (Sub-area 6, Figure 3). Damaging slope failures in the county portion of the hills in 1978 and in other years have been relatively sparse and minor.

The Culver City part of the Baldwin Hills makes up less than one square mile of the hills. Damaging slope failures have been common in the small portion of Culver City that makes up the southwestern edge of the hills (Sub-area 4, Figure 3). Slope failures have also occurred in the portion of Culver City in the northwest part of the hills (Sub-area 1, Figure 3).

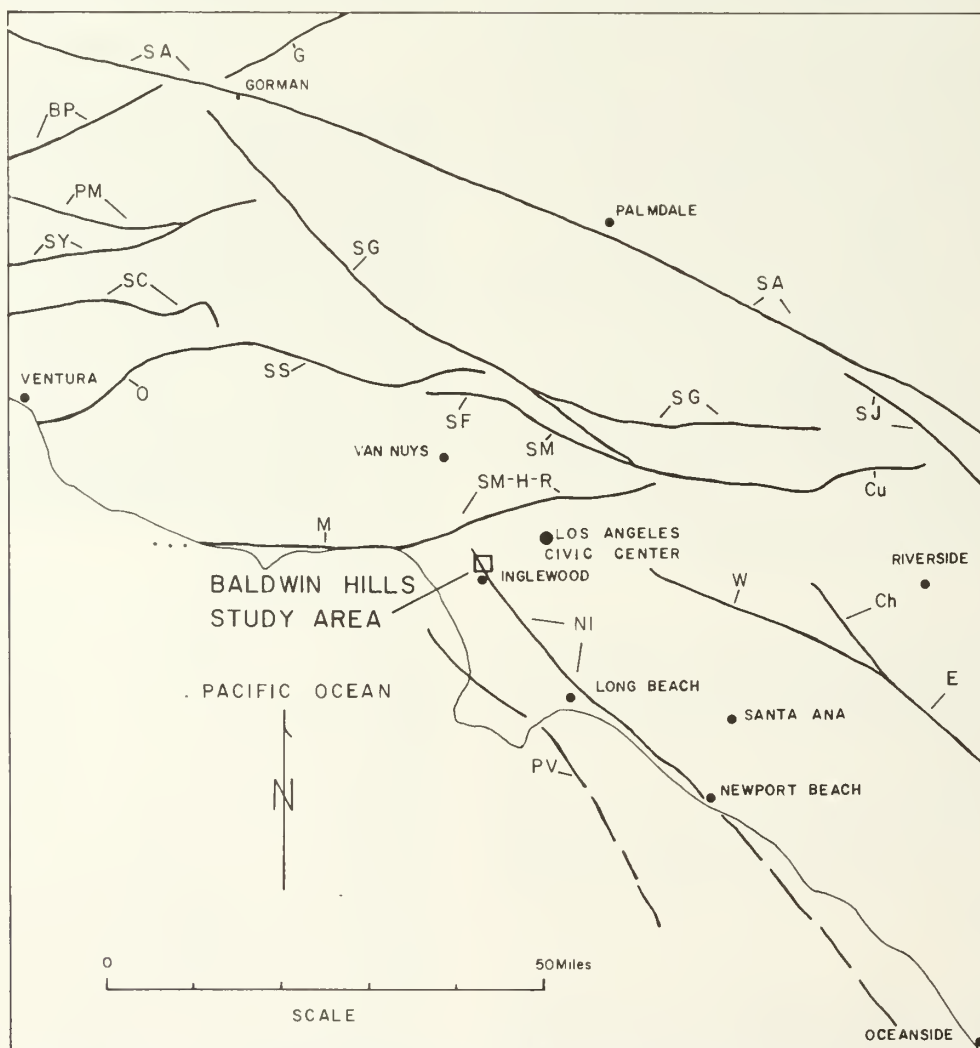


Figure 1. A portion of southern California showing study area and faults. (Faults: BP, Big Pine; Ch, China; Cu, Cucamonga; E, Elsinore; G, Garlock; M, Malibu Coast; N-I, Newport-Inglewood; O, Oakridge; PM, Pine Mountain; PV, Palas Verdes; SA, San Andreas; SC, San Cayetano; SF, San Fernando; SG, San Gabriel; SJ, San Jacinta; SM, Sierra Madre; SM-H-R, Santo Monica-Hollywood-Raymond; SS, Santa Susana, SY, Santo Ynez; W, Whittier.)

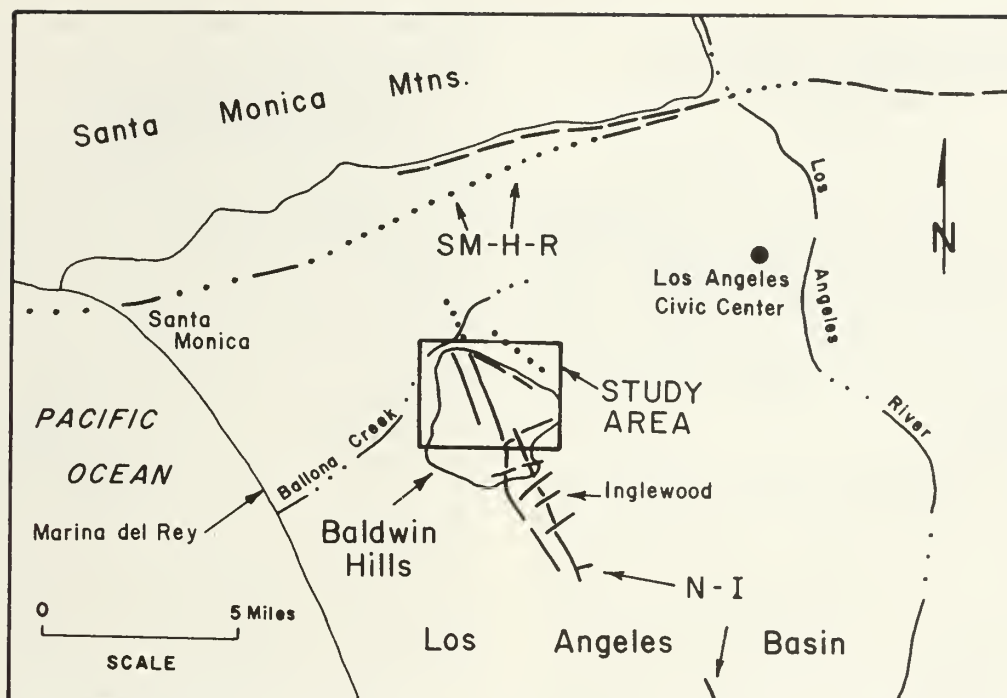


Figure 2. Detail of Figure 1 showing study area and other features of the west Los Angeles region. (Faults: N-I, Newport-Inglewood [structural zone]; SM-H-R, Santa Monica-Hollywood-Roymond [fault zone].)

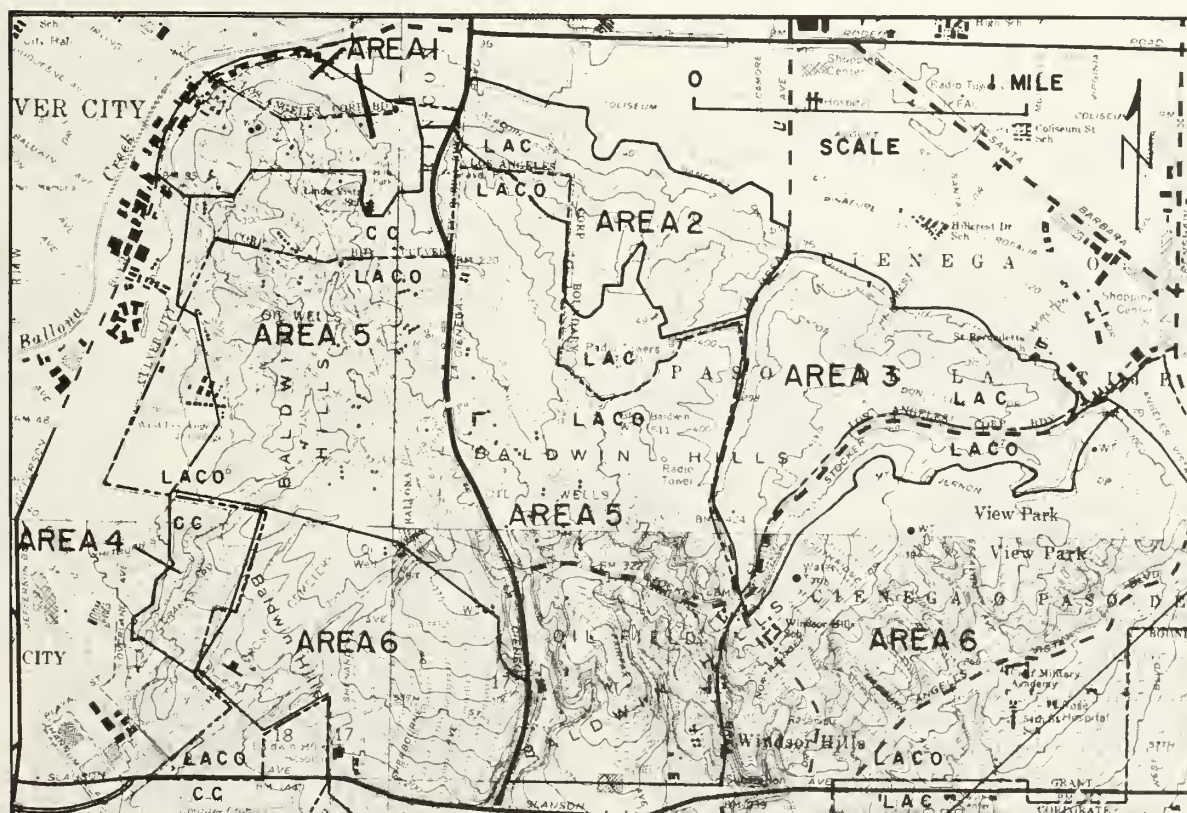


Figure 3. Topographic map showing study area with sub-areas outlined. Sub-areas 1-4 were the principal sub-areas damaged by slope failure in the Baldwin Hills during the 1978 and 1980 rains and, thus, received the most detailed investigation for this study. Also shown on the map are boundaries between local governmental jurisdictions: LACO, Los Angeles County; LAC, Los Angeles City; and CC, Culver City. (The base map is from adjoining parts of the following U.S. Geological Survey 7½' quadrangles, as revised in 1972: Beverly Hills, Hollywood, Inglewood and Venice.)

FACTORS THAT RELATE TO SLOPE INSTABILITY AND FAILURE IN THE BALDWIN HILLS

Geologic Setting and Topography*

The Baldwin Hills are the largest and most prominent of the groups of hills that extend in a line along the Newport-Inglewood structural zone from northwest to southeast in the western and southern parts of the Los Angeles Basin (Figure 2). The hills consist of a dome-like prominence, with steeper northern and gentler southern slopes. The maximum elevation, near the center of the hills, is 511 feet. The surface of the hills slopes generally southward to elevations of 150-200 feet at the south edge of the study area.

The steepest canyons, gullies, and ravines are associated with, and adjoin, the steep escarpment that makes up the north flank of the hills (Figure 4 and Photos 1 to 3). This escarpment overall has a maximum slope angle of about 25°, with a maximum slope height of about 200 feet, and elevations ranging from about 400 feet at the top to 200 feet and slightly lower at the bottom. Individual slopes within the escarpment are steeper than 25°, and natural slopes within canyons adjoining the escarpment are as steep as, and locally exceed, 45°. As was pointed out earlier, this area of steep canyons and the escarpment, including both cut and fill and natural slopes, mostly in the City of Los Angeles, suffered the greatest slope-failure damage in the Baldwin Hills

*By F.H. Weber, Jr.

caused by the rains of 1969, 1978, and 1980, as well as other years (Weber and others, 1978; Weber, 1980; Los Angeles County, 1978; Los Angeles City, 1979).

A moderately high escarpment also borders the west edge of the hills, along the east edge of Ballona Creek flood plain. Residential areas developed along this escarpment, mostly in Culver City, also have suffered damage from the effects of the rains.

The Baldwin Hills lie across, and are an expression of, the Newport-Inglewood structural zone, which comprises a complex system of faults and folds that extends from west Los Angeles southeastward through the Inglewood-Long Beach areas of Los Angeles County, into Orange County, and may extend offshore southeastward toward the San Diego area and perhaps beyond (Barrows, 1973, 1974; Jennings and others, 1975). The Baldwin Hills consist of a gently arched dome, slightly elongated in a northwesterly direction, which is breached by a north-northwest trending graben (a down-dropped block). Within this graben, late Quaternary sediments are displaced downward along the Inglewood fault on the east side and an unnamed fault on the west side (Plate 1 and Figure 5). Castle and Yerkes (1976, p. 5) indicate that 3,000 to 4,000 feet of right lateral displacement has occurred along the Inglewood fault since middle or late Pliocene time, and that 1,500-2,000 feet of right lateral displacement in Quaternary time is suggested by the apparent offset along the fault of topographic features of the Baldwin Hills.

The Inglewood fault, which essentially bisects the study area from north-northwest to south-southeast, is perhaps best exposed in a cut on the east side of La Cienega Boulevard about 1,600 feet south of Rodeo Road (Plate 1). Partly because the

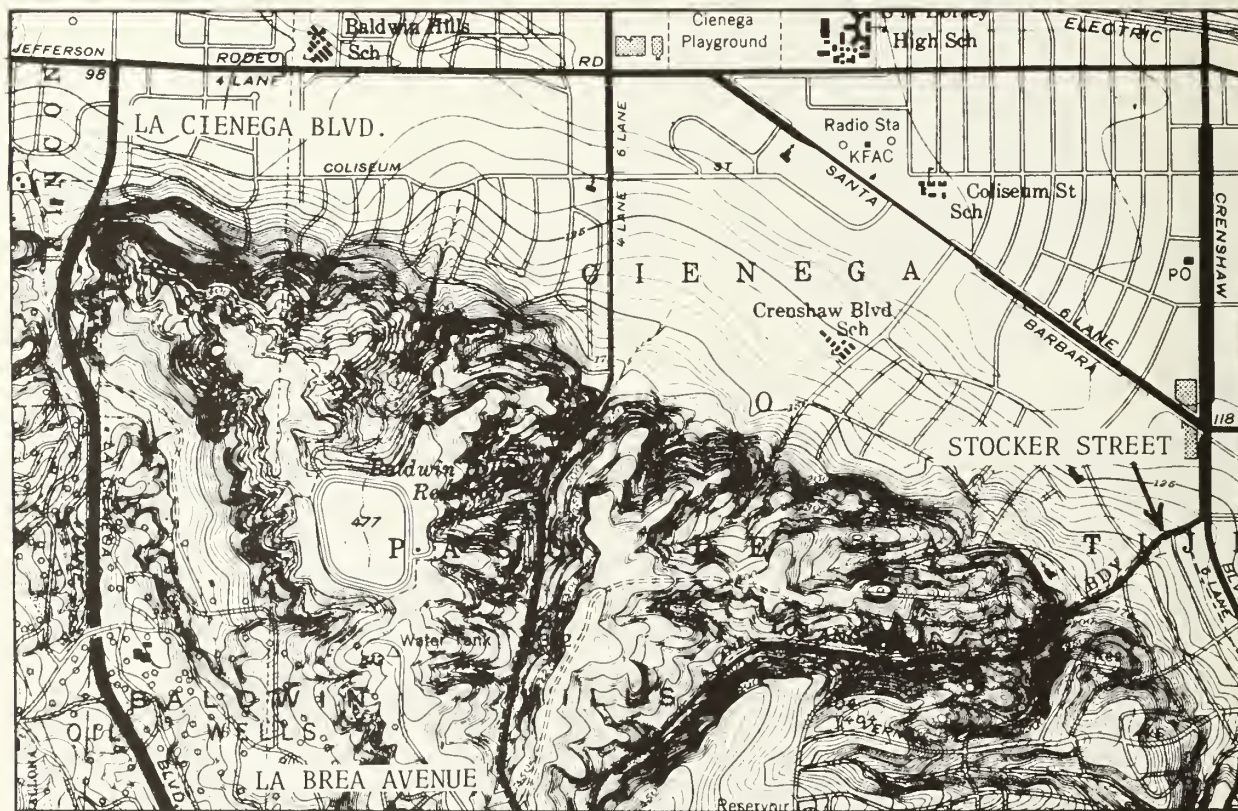


Figure 4. Steepness of the north flank and adjoining terrain of the Baldwin Hills is highlighted by the closely spaced 5-foot contours of a part of the U.S. Geological Survey 7½-minute Hollywood quadrangle (1953 edition). Failure of steep, modified slopes caused widespread damage in 1978.

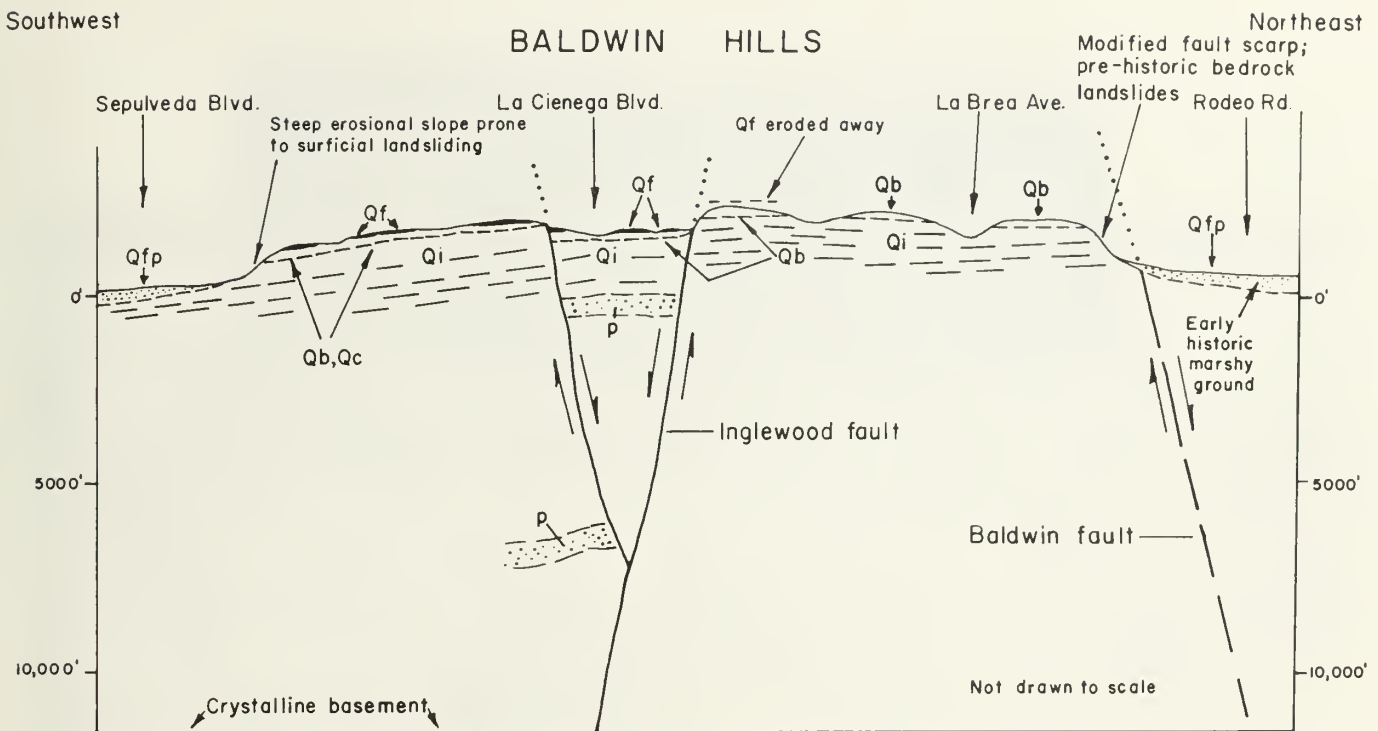


Figure 5. Schematic cross section from southwest to northeast through the Baldwin Hills showing simplified geologic and topographic relationships. (Explanation: Qi, Inglewood Formation; Qb, Baldwin Hills sandy gravel; Qc, Culver sand; Qf, Fox hills relict paleosol; Qfp, flood plain deposits; P, sands from which petroleum has been recovered.)

bedrock in the cut is weakened by its association with shearing and fracturing along the fault, during rainy periods the steep cut readily yields debris flows and eroded material which commonly make La Cienega Boulevard impassable and adds considerably to wet weather traffic congestion in the area (Photo 16).

The Baldwin Hills have been mapped geologically in detail by Castle (1960a), whose map constitutes the principal source of data for the geologic portion of Plate 1 that accompanies this report. Castle's map is accompanied by a table in which the lithologic characteristics of the rock units of the area are described and which formed the basis for Table 1 (herein). Various additional aspects of the geology of the study area are described or noted in reports listed in "References Cited."

The rocks and sediments that make up the terrain of the Baldwin Hills are very youthful. They all formed during the Quaternary period, the most recent period in geologic time, extending back only about 2 million years. The recent uplift of the hills from below sea level attests to continuing tectonic activity (accompanied by earthquakes) in the area during latest Quaternary time. In addition, the youthful sediments that have been uplifted are very weakly indurated and cemented and thus the steep topography developed in them is extremely vulnerable to landsliding and erosion, effected principally by sustained, heavy rainfall.

Rainfall*

Based on the history of rainfall over the past 100 years, the period for which records have been kept, the threshold of sufficient rainfall to cause at least a moderate number of slope failures in southern California is reached statistically, on an average, in about three or four winters in ten, when accumulated yearly

rainfall reaches about 19 inches at Los Angeles Civic Center (Weber and others, 1978, p. 22 and Table 1). Additionally, rainy years tend to occur in wet-dry-wet cycles that last about 25 years (Weber and others, 1978, Table 1). Thus, in southern California, several very rainy years can, and have, occurred in one decade (the 1930s, for example), followed first by a period during which rainy years are sparse and then by another period with several closely spaced wet years that begins a new cycle.

Thus can be envisioned a setting for the Baldwin Hills before cultural development of the landscape began, marked by alternating wet and dry periods, with the wet periods commonly accompanied by widespread surficial landsliding and erosion, and less widespread deep-seated landsliding, in the steep natural slopes of the northern part of the hills (Photos 1 - 4 and 7). Debris from surficial landsliding and erosion during these periods was transported by streams to the edge of the hills, deposited upon alluvial fans (Photo 8) and carried into the flood plain of Ballona Creek and other drainages.

Starting with the oil field in 1924, development within the Baldwin Hills began to alter the natural pattern of erosion, landsliding, and stream flow—processes that, until that time, had proceeded without interruption and had yielded alluvial fans and added to flood plain deposits. With residential development of the northern part of the hills in the very late 1940s and the 1950s, the steep natural slopes that were already vulnerable to erosion and landsliding were modified into steeper, graded slopes that were even more vulnerable to slope failure caused by sustained heavy, winter rainfall.

Since development of the Baldwin Hills began in the very late 1940s, 19 or more inches of rain have fallen at Los Angeles Civic Center during the winters of 1951-52, 1957-58, 1968-69, 1977-78, and 1979-1980. The most serious and most widespread damage in the Baldwin Hills occurred in March 1978; affected residents were extremely surprised by the magnitude of this damage, perhaps because a large percentage of them had moved into the area

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Photo 1. Aerial view on February 1, 1939, looking west toward the steep north flank of the Baldwin Hills, which is a modified fault scarp. (Explanation: A, Baldwin Hills; B, Inglewood oil field; C, Santa Barbara Avenue; D, Leimert Boulevard; E, Stocker Street; F, Santa Monica Mountains; G, Santa Monica Bay.) Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.



Photo 2. Aerial view west on February 25, 1936, shows steep escarpment along the north side of the Baldwin Hills which, at that time, were developed essentially only by the Inglewood oil field. Ancient bedrock landslide and possible ancient (questioned) bedrock landslides outlined on the photograph exemplify the slope instability of the natural terrain of the Baldwin Hills before it underwent residential development. Lower right hand corner of photograph shows a vestige of the morshy ground (M) that was once fairly widespread in the area north of the hills. (Additional symbols: LB, La Brea Avenue; SB, Santa Barbara Avenue, GC; golf course.) Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.



Photo 3. Aerial view on December 21, 1941 looking vertically downward on the Baldwin Hills. Photo shows the sharpness of the modified fault scarp that makes up the north boundary of the hills; the photo also shows the steep slopes that make up the modified scarp and the adjoining topography that was developed in the late 1940s and the 1950s. Note the ancient bedrock landslide (Qls) and apparent bedrock landslides (Qls?) that can be identified on this photo. The east boundary of the Inglewood oil field marks the trace of the Inglewood fault which is shown on Plate 1. (Explanation: A, Stacker Street; B, Crenshaw Boulevard; C, Lo Brea Avenue; D, Jefferson Boulevard.) Photograph is from the Fairchild Collection, Whittier College.

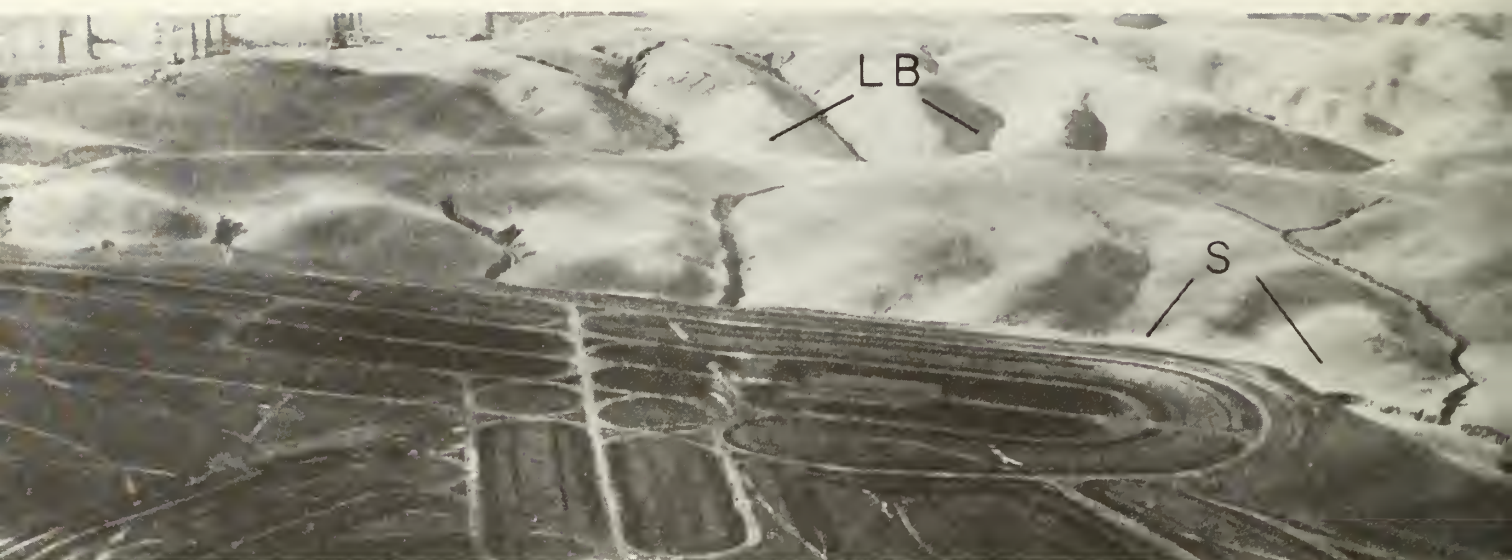


Photo 4. Aerial view westerly on February 9, 1932 shows site in preparation for athlete's village for 1932 Olympic games. The site is just east of the canyon (S) that now contains Stocker Street. The village site was later developed residentially as a part of View Park and Windsor Hills. Incised drainages occur in Stocker Street canyon and canyons to east of Stocker Street and west of the canyon (LB) that now contains Lo Breo Avenue. Incision of the drainages could have been the partial result of relatively recent tectonic uplift of the Baldwin Hills. Incision also could have been partially caused by the heavy rains of the winter of 1931-32 flushing colluvium out of the canyon bottoms. Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.

since 1969, the last period of widespread damage from heavy rainfall in southern California.

Most periods of damaging rainfall in southern California "sneak up," so to speak, as suggested by Figures 6a-c. These figures comprise graphs of rainfall for the winters of 1968-69, 1977-78, and 1979-80 recorded at Inglewood Fire Station 116D, which is just south of the study area. In each of these winters the amount of rainfall early in the season did not suggest that large amounts of closely spaced rainfall would occur later. In 1968-69, only about 2.5 inches of rainfall had fallen at the fire station by January 14, 1969, but 12.4 inches fell from January 17 to 28, and 10.7 inches from January 19 to 25. This latter period of rainfall produced very destructive damage from flooding and landsliding in southern California (Campbell, 1975). In 1977-78, 9 inches of rain fell by January 9, 1978, but very little rain fell from then until about February 1. From February 1 to February 14, about 7 inches fell, although with little effect on the Baldwin Hills, followed by another fairly dry period that lasted until about February 25. From that day through March 5, however, about 8.5 inches of rain were recorded at the Inglewood Fire Station. It was the steady rainfall on March 4-5 that triggered widespread slope failures in the Baldwin Hills.

In the winter of 1979-1980 only 1 inch of rain fell in the Baldwin Hills by January 8, 1980, and only 8 inches fell by February 12. From February 12 to 21, however, about 10 inches of rain were recorded at the Inglewood Fire Station, and a moderate number of slope failures occurred in the Baldwin Hills. From March 2 to 5, 5.4 inches of additional rain fell, but it caused very little damage. The 1980 rains probably caused slopes to fail in the hills that were "spared" by the 1978 rains. The rains of 1978 and 1980 caused slides and flows to originate in the steep graded slopes whose instability had been evolving through a process involving weathering, poor maintenance, and general deterioration caused by gopher-digging and other factors since they were graded in the very late 1940s and the 1950s. This growth of instability had been interrupted by actual slope failure caused by heavy rains only in 1952, 1969, and a few other years.

In conclusion, even during cyclic periods when winters that yield large amounts of damaging rainfall should be anticipated, it is difficult to forecast the occurrence of such rainfall at the beginning of winter. In addition, in some years very rainy periods may occur even after the month of January and part of February have been relatively dry. Meteorologists can tell much better by the end of January or early February whether the remaining part of a winter will be rainy or dry.

Rock Units*

Following are generalized descriptions of the lithology and slope stability characteristics of the rock units of the Baldwin Hills area, accompanied by more detailed data in Tables 1 and 2.

Inglewood Formation (Qi)

The upper (Pleistocene) part of the Inglewood Formation, a name introduced by California Department of Water Resources (1964), is exposed mainly in the lower portions of steep slopes in the northern part of the Baldwin Hills and in slopes along the east side of the Inglewood fault in the central part of the hills (Plate 1). The unit was called "A formation" by Castle (1960a). The sediments of the Inglewood Formation were deposited in a shallow marine environment. Rocks of the unit are overlain unconformably by coarser-grained rocks of the Culver sand and the Baldwin Hills sandy gravel, which were deposited in near-shore marine and nonmarine fluvial environments, respectively.

The Inglewood Formation consists principally of thinly interbedded, light-brown to gray-brown, well-consolidated siltstone and very fine-grained sandstone which locally are clay-rich and which commonly contain calcareous and limonitic concretions. The sandstone generally is slightly coarser near the top of the unit; otherwise the lithology is relatively uniform. In contrast

*By E.Y. Hsu, R.B. Saul, and F.H. Weber, Jr.

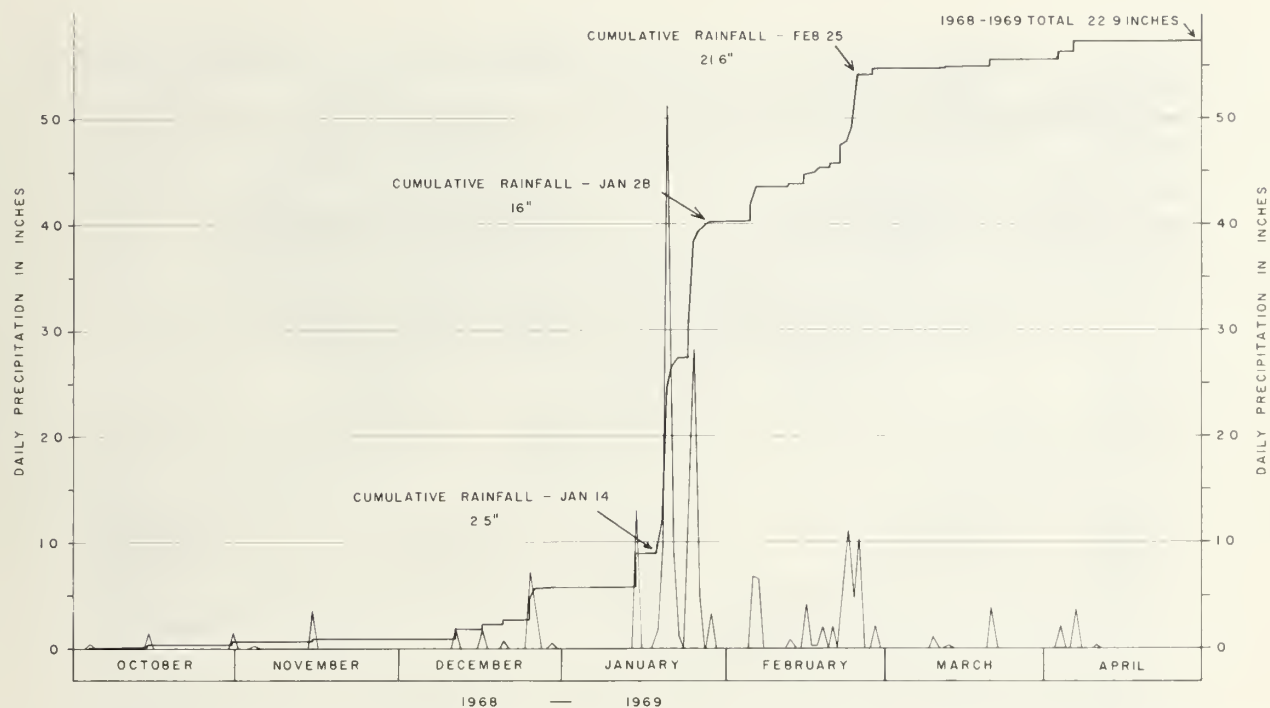


Figure 6a. Principal precipitation during 1968-69, at Inglewood fire station 116D, just south of the study area (latitude $33^{\circ} 57' 53''$ and longitude $118^{\circ} 21' 22''$; elevation 153 feet). Principal slope failures occurred in the Baldwin Hills during the intense rains of late January 1969, after the ground was saturated by rain earlier in the month.

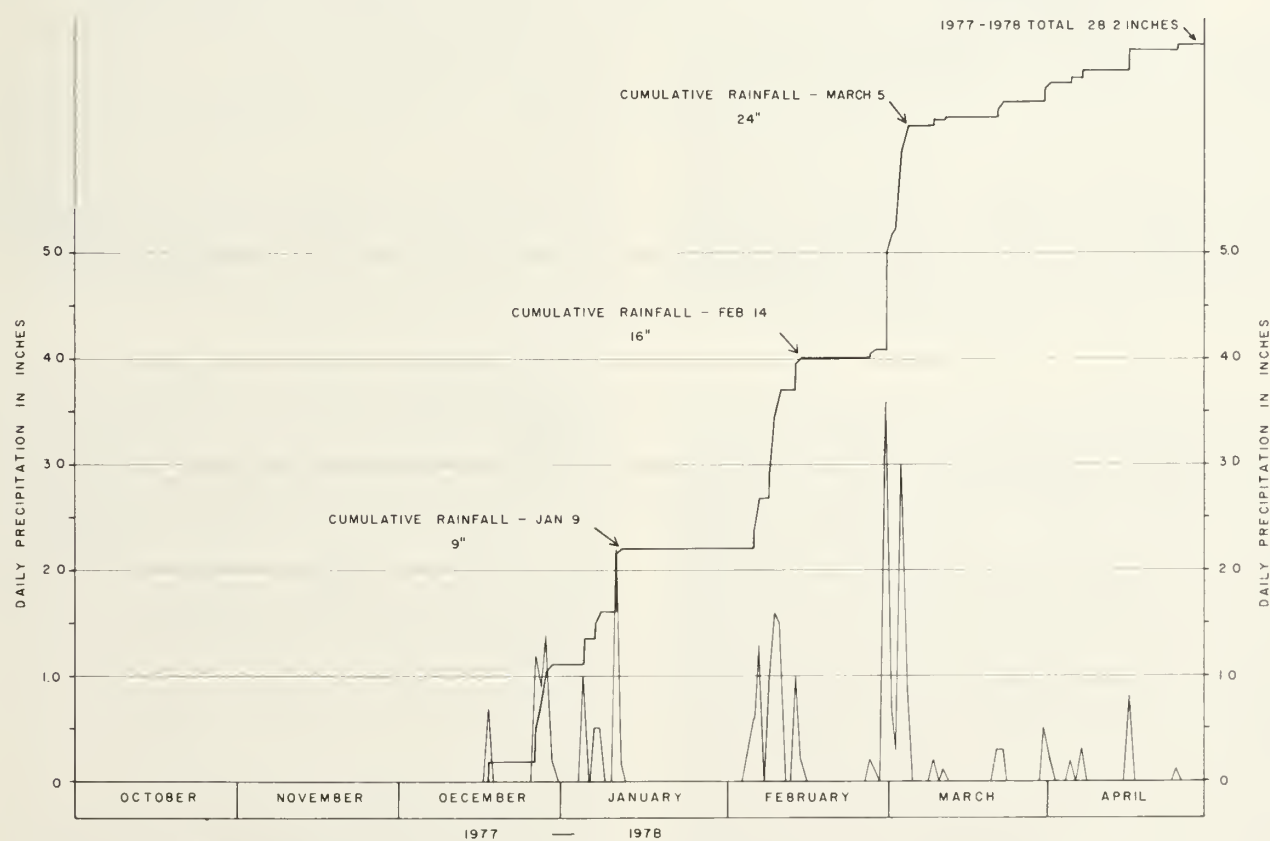


Figure 6b. Principal precipitation during 1977-78, at Inglewood fire station 116D. Principal slope failure in the Baldwin Hills occurred during the intense rains of late March 4-5, 1978, after earlier rains had saturated the ground.

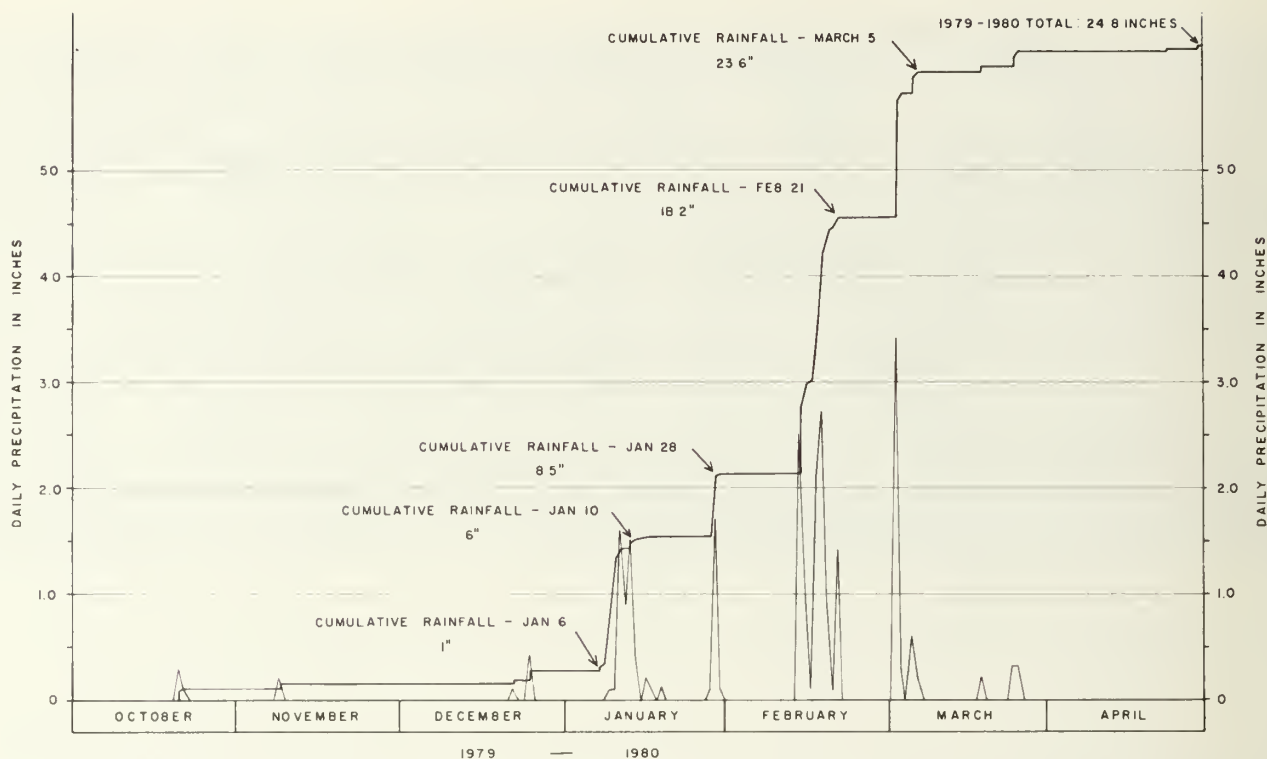


Figure 6c. Principal precipitation for 1979-1980 at Inglewood fire station 116D. Slope failures in the Baldwin Hills occurred during February and March 1980.

with the non-cohesive and friable nature of the overlying, less expansive Culver sand and Baldwin Hills sandy gravel, rocks of the Inglewood Formation are generally dense and moderately expansive when weathered (Table 1). A relatively higher incidence of surficial failure may have occurred in slopes underlain by this unit than slopes underlain by other units, which is the result of the more clayey soil and slope wash that tends to develop on this unit more than on other units. Most of the bedrock landslides in the Baldwin Hills are derived from these rocks, apparently because of their clay content and because they are thinly-bedded, more fractured than the overlying rocks, and commonly dip adversely (downward) out of slopes.

Culver Sand (Qc)

Culver sand is a name that was adopted informally for this study. The unit makes up the lower part of the "B" formation of Castle (1960a). It is exposed mainly in the northwestern and western parts of the Baldwin Hills, where it rests unconformably on the Inglewood Formation. It is overlain both conformably and in erosional unconformity by the Baldwin Hills sandy gravel (Qb). The unit reaches a maximum thickness of about 100 feet.

In the area just northeast of West Los Angeles College, the Culver sand consists predominantly of crudely stratified to laminated, light brown, poorly consolidated and partly sorted, fine- to coarse-grained sand interbedded with lenses and thin beds of gravel. The sand beds are typified by large scale cross-bedding oriented in such a way as to indicate sediments of the unit were derived from the north. The gravel beds are commonly composed of well-rounded and hard pebbles of metavolcanics, vein quartz, quartzite, chert, jasper, and chalcedony; less common are anorthosite and Lowe Granodiorite. Chips of slate and cherty shale are locally abundant. Coatings of iron oxide are common in exposures of gravel but less common in exposures of sand.

Both sand and gravel are poorly cemented and, therefore, commonly subject to erosion (Photo 5).

From just northeast of West Los Angeles College, the sand and gravel facies described above grades southerly and easterly into well-laminated fine- to medium-grained sand with scattered small pebbles. Directly east of the college, the sand contains some thin beds of gray, dense, clayey siltstone which appears to be expansive in some exposures. The sand facies is better cemented and denser than the sand and gravel facies to the north. Slopes underlain by both facies, however, are prone to erosion.

Baldwin Hills Sandy Gravel (Qb)

Baldwin Hills sandy gravel (Qb) is a name adopted informally for this study. The unit consists of the upper part of the "B formation" of Castle (1960). It is the most widely exposed rock in the Baldwin Hills, occupying nearly two-thirds of the area, commonly capping ridges. In the western part of the study area, it rests on Culver sand (Qc), in both erosional and transitional contact. East of La Cienega Boulevard, it unconformably overlies the Inglewood Formation. The thickness of the Baldwin Hills sandy gravel is variable, ranging from about 50 feet to perhaps 100 feet, because of the complex nature of the ancient river deposits that make up the unit (see Figures 8 and 9).

The Baldwin Hills sandy gravel consists of two facies: one of sand and gravel and one of clayey silt. The sand and gravel facies is typified by exposures east of La Cienega Boulevard, whereas the clayey silt facies is exposed mainly west of the boulevard. The sand and gravel facies generally overlies the silt facies with an erosional unconformity, but laterally the units are in transitional contact. The sand and gravel facies of the unit consists of thick beds of poorly sorted gravelly sand with scattered lenses of gravel. Pebbles and cobbles of the gravel are generally angular to subangular. Beds are crudely stratified to massive. Locally,



Photo 5. Culver sand (Qc, Plate 1) is exposed in a cut near an oil well in the Inglewood oil field. The sand-silt mixture that has been washed down to the base of the cut has dried firm because it contains a small proportion of clay with which the parent unit is cemented. The original cut was graded at an angle of about 55° and oiled to inhibit erosion. With the washing away of the coating of oil, erosion established the near-vertical profile of badlands topography that this rock tends to develop when exposed to runoff.

clayey silt beds are present. The sandy deposits commonly contain fragments of silt and clay that obviously were scoured from clayey or other soft beds deposited previously.

The clayey silt facies of the unit consists of yellowish green to light gray, clayey silt with interbeds of angular-grained, sandy gravel and massive to laminated sand. Sand beds generally grade upward into overlying silt beds. The clayey silt beds are generally dense and hard, and more resistant to erosion than the sandy deposits. Clay beds, about 4 inches to one foot thick, that are rich in organic remains, occur at the base of this unit in the Inglewood oil field. Because these beds have been oxidized to a dark brown color and contain abundant gypsum and jarosite, of secondary origin, they are highly visible and thus constitute useful key (or index) beds for mapping (Photo 9).

The more sandy and gravelly deposits of the Baldwin sandy gravel contain more clay than similar beds of the Culver sand, which causes this unit to be better cemented. Both units, however, are prone to erosion; thus, badland topography and gullies resulting from erosion are common in terrain underlain by both units.

Fox Hills Relict Paleosol (Qf)

The Fox Hills relict paleosol is an informal name that was adopted for this study. The unit was called "Cap deposits" by Castle (1960a). The paleosol was developed on a surface underlain mainly by the Baldwin Hills sandy gravel (Photo 6). The paleosol consists of reddish brown, well-cemented and resistant

silty sand that occurs mostly in the southwestern part of the Baldwin Hills, mainly west of La Cienega Boulevard. The sands are locally pebbly to gravelly. Vertical fractures are clay-coated. The thickness of the paleosol ranges from 5 to 10 feet and greater. The unit is very impermeable.

Pre-development Landslides (Qls)

The only ancient, large pre-development landslide to be well-identified in the study area is on the north flank of the western part of the Baldwin Hills (Plate 1, east of Slope failure locality 1b). To the east, on the north flank of the hills, several landslides have been reasonably well identified on pre-development aerial photographs (Photos 2, 3 and 7), but their authenticity has not been verified by on-site geological methods (see Plate 1 and Figures 7a and 7b). Additional features that have been tentatively identified from pre-development aerial photographs and topographic maps as possible landslides are shown on Figures 7a and 7b and in Photos 2 and 8. Most of the features identified as pre-development bedrock landslides or possible bedrock landslides occur within terrane of the Inglewood Formation (Qi, Plate 1). This unit commonly is more unstable than rocks overlying it, because it is more clayey, more thinly bedded, more fractured, and because the angle of its dip is more adverse.

The incidence of surficial landslides and erosion may be higher in terrain that is underlain by ancient bedrock landslides than terrain underlain by bedrock that has not slid. This is because a bedrock mass that has structurally failed, even if it is relatively

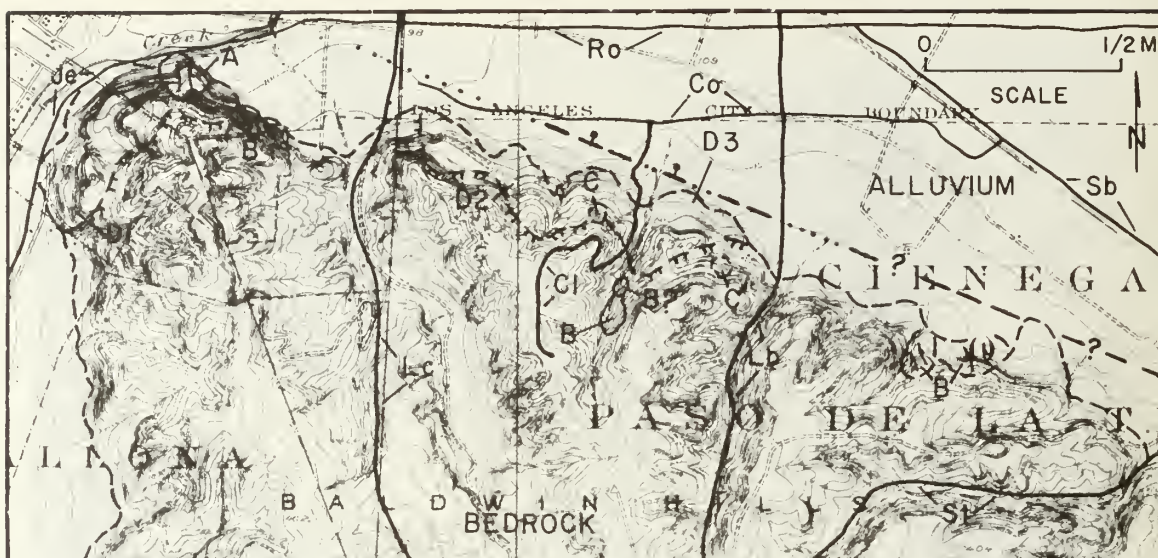


Figure 7a. Portion of U.S. Geological Survey Hollywood 6-minute quadrangle (1926 edition, contour interval 5 feet) showing undeveloped steep topography and types of ancient landslides and probable and possible ancient landslides derived from bedrock in the northern Baldwin Hills: A, well-identified (arrows show direction of sliding) (Photo 7); B, probable landslides, as identified on predevelopment aerial photographs (arrows show direction of sliding where appropriate) (Photos 3 and 7); C, possible landslides, as identified on pre-development aerial photographs; D, bedrock areas identified as possible landslides because of unusual topography depicted on this map or as shown on aerial photographs (D1, D2, and D3; Photos 2 and 8). Bolls on fault face in direction of opposite scarp in youthful alluvium, as shown on Photo 8. (Additional symbols: Co, Coliseum Street; Cl, Cloverdale Avenue; Je, Jefferson Boulevard, LB, Lo Breo Avenue; LC, Lo Cienega Boulevard, Ro, Rodeo Road; St, Stocker Street; SB, Sonto Borboro Avenue).

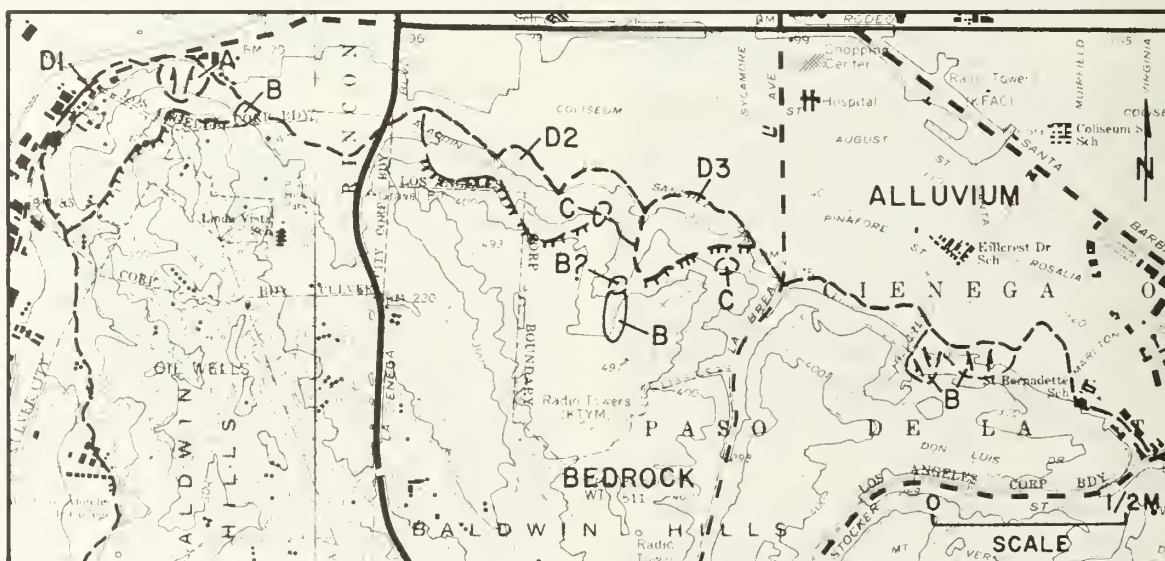


Figure 7b. Portions of adjoining Hollywood and Beverly Hills 7 1/2-minute quadrangles (1972 editions), showing developed northern Baldwin Hills and four types of bedrock landslides and probable and possible bedrock landslides: A, well-identified landslides; B, probable landslides; and C and D 1-3, possible landslides. (See Figure 7a for further explanation.)



Phata 6. View shows Fax Hills relict paleasal (Qf) which caps ridges and terrace surfaces in the Baldwin Hills ond is easily recognized by its red-brown color. This material ranges locally somewhat in texture and firmness but, in general, consists of firmly clay-banded, paarly sarterd, pebbly to gravelly sand. It is the mast stable rock unit in the Baldwin Hills. The vertical fractures are clay-coated. Because it is generally impermeable, the unit canstitutes a hazard where percolation is required.



Photo 7. Aerial view south in 1936 at the northwestern edge of the Baldwin Hills shows ancient landslides that are mapped on Plate 1. The number "57" refers to an oil company apering in the area at that time. Trench (T) exposes a succession of Quaternary sediments described earlier by Tieje (1926). (Symbols designate sites or future sites of additional features as fallows: BC, Ballana Creek; CC, Culver City; J, Jefferson Baulevord; LB, La Brea Avenue; LC, La Cienega Baulevard; R, Radea Road.) Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.

TABLE 1. DESCRIPTIONS OF ROCK UNITS IN THE BALDWIN HILLS ⁽¹⁾ By E.Y. Hsu

NAME AND MAP SYMBOL (PLATE 1)	LITHOLOGY	SOIL DEVELOPMENT AND WEATHERING	PROPENSITY TO SLOPE FAILURE DURING SUSTAINED HEAVY RAINFALL		
			EROSION SUSCEPTIBILITY	SURFICIAL SLIDES AND FLOWS	MASSIVE SLIDES (SLUMPS, GLIDES)
Artificial fill af	Rock material derived from geologic unit adjacent to fill site as shown on Plate 1. Locally may include trash and other inert debris.	No soil developed. Depth of weathering probably not more than 3 feet.	Moderate to high; erosion gullies common.	High in improperly compacted or loose fill. Low to moderate for compacted fill.	May be subject to massive failure if not properly benched into firm bedrock.
Undivided colluvium and alluvium within and around periphery of the Baldwin Hills Qco	Mainly unconsolidated, poorly sorted and poorly bedded sand, gravel and silt. Deposits derived from Qb and Qc are more gravelly and sandy than those derived from Q1. Deposits in the area of low relief north and west of the Baldwin Hills are more indurated than those in the hills.	None in most recent deposits to moderate soil development on older deposits. "A" horizon generally is less than 2 feet thick. Weathering generally less than 6 feet but locally is greater than 10 feet in depth.	Moderate to high; erosion gullies common in sandy alluvium and colluvium.	Moderate to high in stream banks.	Small slumps may occur in stream banks.
Floodplain, stream channel and marsh deposits of Ballona Creek Qfp, Qfpm and Qfpu	Qfp: chiefly well-sorted and moderately well-bedded fine to medium grained unconsolidated to very poorly consolidated sand; locally underlain at depths of 5-10 feet by clean gravelly material. Qfpu: slightly uplifted and more indurated than Qfp. Qfpm: historically marshy ground underlain by deposits rich in organic material.	Moderate soil development up to 6 feet thick of loamy clay; "A" horizon probably less than 2 feet in thickness.	Low to moderate; erosion gullies common.	Very high in banks of gullies and channels.	Small slumps may occur in sides of swales and in banks of creeks.
Pre-development landslides Qls	Lithology is variable, depending on geologic units from which derived. Most pre-development landslides consist of deep-seated masses of intact or brecciated bedrock; some consist of shallower masses of soil and colluvium (Locality 15a, Plate 1, for example).	See, elsewhere in column, units from which landslides are derived.	Higher than in source rocks from which landslides are derived.	Moderate to high.	Reactivation of pre-development landslides may be caused by such factors as heavy loading on surface and excessive infiltration of water into slide plane.
Fox Hills relict paleosol Qf	Reddish brown silty sand with scattered gravel. Clay binder common. Very well-cemented and hard. Generally massive to crudely stratified. Locally well laminated.	None to poorly developed. "A" horizon is generally less than 2 feet in thickness.	Low for well cemented materials; moderate to high for weathered zones.	Very low. Weathered zone may be subject to debris flows.	Cut slopes 3/4:1 or steeper and 15 feet high have been known to stand for one year without failure.
Baldwin Hills sandy gravel Qb	Predominantly brownish gravelly, silty sand with lenses of gravel and thin beds of silt and clay. Coarse beds are generally massive to crudely stratified and are generally slightly to moderately cemented but may contain clean loose sand. Clasts of gravel are typically angular. Silt and sandy clay are generally well bedded, dense and hard.	Moderate soil development. Soil developed on sand and gravel is sandy. "A" horizon is generally less than 2 feet thick. Weathering zone is generally less than 5 feet but locally is greater than 10 feet in depth.	Moderate to high; badland topography is common.	Moderate to high.	May be subject to blockglides where underlain by clay or silt with adverse dip (2).
Culver sand Qc	Predominantly interbedded gravel and gravelly silty sand with minor silt lenses. Sands are fine to coarse-grained, loose to slightly cemented. Massive to crudely stratified. Gravel clasts are typically well-rounded. Iron stains and cementation are common.	Poor to moderate soil development. "A" horizon is generally about 1 foot thick. Weathering zone may be less than 6 feet in depth.	High to very high; badland topography common.	Moderate to high.	Low to moderate.
Inglewood Formation Q1	Chiefly light brown to light brown-gray silt to very fine-grained sand with local clay. Generally well-bedded and moderately to well-consolidated. Loose fine sand is abundant in the higher part of the succession, especially in the northwest corner of the hills. Calcareous and iron concretions are locally abundant. Rocks are locally well-jointed.	Moderate soil development. "A" horizon is generally 1-3 feet thick but weathering may be as deep as 10 feet or more. Soil developed contains more clay than soil developed on other units.	Moderate to low.	Moderate to high.	Moderate to high; several probable, ancient landslides identified on aerial photographs during this study and shown on Plate 1 are located in terrain underlain by this unit.

PROPENSITY TO GROUND FAILURE DURING STRONG EARTHQUAKE SHAKING	ENGINEERING PROPERTIES					NAME AND MAP SYMBOL (PLATE 1)
	EXCAVABILITY	DENSITY	EXPANSIVITY	SHEAR STRENGTH	PERMEABILITY	
High in loose fill; loose sandy fill may be subject to seismic compaction and settlement. Moderate to low for well compacted fill.	Easy.	clay = 110-125 pcf silt = 100-115 pcf silty sand = 95-110 pcf clayey sand = 90-105 pcf.	Low to moderate in clayey fill; low in sandy fill.	Generally low but high where properly compacted.	Low in compacted fill. Moderate in loose fill. Sandy fill is more permeable than clayey fill.	Artificial fill af
Lurching may occur in sandy colluvium and alluvium; small surficial slides may occur along steep embankment of erosional gullies or steep cuts.	Very easy.	75-90 pcf.	Low to moderate.	Low to moderate.	Lateral permeability moderate to high in sand and gravel but low in silt or clay. Vertical permeability generally low.	Undivided colluvium and alluvium within and around periphery of the Baldwin Hills Qco
Variable. In areas of low relief where water table is near the surface, sediments may liquefy during severe earthquake shaking, causing severe damage to engineering structures.	Very easy.	90-110 pcf.	Low.	Low to moderate, increasing with depth.	Moderate to high.	Floodplain, stream channel and marsh deposits of Ballona Creek Qfp, Qfpm and Qfpu
Variable; pre-development landslides may reactivate through seismic shaking especially when water-saturated.	Easy.	Generally less than source materials because of numerous fractures.	Low.	Generally lower than that of source materials.	Generally higher than that of unslid rock of the same unit due to presence of numerous fractures in the slide mass.	Pre-development landslides Qls
Moderate sloughing of weathered material may occur from steep cut or natural slopes but generally more stable than other units.	Moderate to difficult.	High below weathered zone; moderate in weathered zone.	Non-expansive; low in weathered zone.	High ($\phi = 18^\circ$, $c = 800$ psf; $\phi = 33^\circ$, $c = 500$ psf); moderate to low portions.	Generally low to very low; moderate where extensively weathered.	Fox Hills relict paleosol Qf
Moderate where deeply weathered; less susceptible below weathered zone.	Easy.	silty sand = 85-105 pcf clayey sand = 105-120 pcf sand = 90-105 pcf sand and gravel = 100-110 pcf.	Non-expansive.	Generally moderate to high ($\phi = 15^\circ$ - 30° , $c = 200$ - 350 psf); low in weathered zone.	Moderate to high lateral permeability in sandy gravel. Poor to moderate vertical permeability.	Baldwin Hills sandy gravel Qb
Moderate where deeply weathered; low below weathered zone. expansive.	Easy.	silt = 85-110 pcf silty sand = 90-110 pcf sand = 100-110 pcf. zone.	Non-expansive; soil developed is slightly expansive.	Generally moderate to high ($\phi = 32^\circ$, $c = 200$ psf); low in weathered zone.	Moderate to high vertical and lateral permeability.	Culver sand Qc
Moderate to very low susceptibility.	Easy.	clay = 100-120 pcf silt = 85-110 pcf silty sand = 90-100 pcf clayey sand = 100-120 pcf sand = 90-120 pcf.	Moderate.	Generally moderate ($\phi = 20^\circ$ - 35° , $c = 100$ - 300 psf); low in weathered zone.	Generally low, but moderate lateral permeability may occur in loose sand portions of the unit.	Inglewood Formation Qi

NOTE: (1) Data presented in this table are general and should not be used as a substitute for site-specific studies and engineering design.
 (2) Slope failure propensity increases as the angle of adverse dip increases. (The term adverse dip indicates that the bedding dips downward out of the slope.)



Photo 8. Aerial view south, probably in the early 1940's, shows essentially natural terrain in vicinity of the canyon in which Cloverdale Avenue was later constructed. Probable and possible landslides shown (A and B) are also depicted on Figures 7a and 7b, and landslide C is shown on Plate 1. Note that the apparent north-facing fault scarp (D) is very youthful, overlain only by the most recent alluvial fan deposits from the canyon; incision of drainage in fan shown with arrow (E) probably occurred since latest movement on fault. (Additional symbols: F, Lo Breo Avenue; G, Coliseum Avenue; H, site of future Cloverdale Avenue.) Photograph is from *History Division, Los Angeles County Museum of Natural History*.

TABLE 2. SOIL TEST DATA FOR SUB-AREAS 1-4 (Sample locations are shown in brown on Plate 1.)

By E.Y. Hsu, S.S. Tan, and J.A. Treiman

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (% dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in % dry weight; angle of internal friction (ϕ) and cohesion (C, psf) of sample remolded to 90% compaction (2) (3)	Source of data (4)
(SUB-AREA 1)							
#1 9300 Jefferson Blvd.	Sandy silt: Fine sand (Qi):			28° 32°	150 150		Aako Geotechnical Consultants, Inc. 8/8/80
#2 3955 Shedd Terrace	Fine-grained clayey sand: Sandy silt (af):	99.3 104.8	16.9 7.2	25° 25°	200 300	Silty sand: MDD = 125 OM = 11% Sandy silt: MDD = 109 OM = 17% Silty sand: MDD = 109 OM = 13% Expansion index of silty sand fill = 10 (low potential of expansion)	Lockwood-Singh & Associates 7/5/79
#3 6003 Wrightcrest Dr. Tract 22920 Lot 18	Fine to medium sand (Qco): Silt to clay (af): Silty sand (Qc):	94-103 89-110 95-109	4.1-6.5 6.0-15.4 3.6-8.6	32°	200		LeRoy Crandall and Associates 4/9/80
#4 3849 Perham Dr. Tract 22920 Lot 20	Silty sand (Qc):	91-97	4.6-6.8	32°	200		LeRoy Crandall and Associates 2/2/80
#5 5949 Wrightcrest Dr. Tract 22920 Lot 16 Parcel C	Silt: Silty sand: Fine to medium-grained sand (Qc):	94-102 93-108 106-110	9.0-18-0 5.1-12.9 3.7-5.0	32°	200		LeRoy Crandall and Associates 2/2/80
(SUB-AREA 2)							
#6 5744 Brushton St. Tract 15116 Lot 74	Fill (af):					Silty to sandy clay MDD = 119, OM = 13.5% Clayey to sandy silt MDD = 123, OM = 12.5%	Soils International 11/31/79
#7 5731-5751 Aladdin St. Tract 14474 Lot 1-4	Silty clay (Qi):					$\phi = 30^\circ$, C = 0	Soils International 3/13/79
#8 5637 Aladdin St. Tract 14474 Lot 15	Fill (af): Clayey silt (Qco):	96.1 106.3	20.7 18.5			MDD = 116, OM = 14% MDD = 119, OM = 14%, $\phi = 16^\circ$, C = 450	Lockwood-Singh & Associates 10/18/79; 10/3/78 9/12/78
#9 4143 Cloverdale Ave. Tract 19051 Lot 28	Sandstone and siltstone (Qi):					$\phi = 35^\circ$, C = 270 $\phi = 30^\circ$, C = 300 $\phi = 28^\circ$, C = 185 MDD = 106, OM = 20%	Amdex, Inc. 5/9/79

TABLE 2. (continued)
SOIL TEST DATA

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (% dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in % dry weight; angle of internal friction (ϕ) and cohesion (C, psf) of sample remolded to 90% compaction (2) (3)	Source of data (4)
#10 4131 Cloverdale Ave. Tract 19051 Lot 26	Fill (af):	91.5	17.3	30°	200		Lockwood-Singh & Associates 11/13/79
#11 5428 Weatherford Tract 15390 Lot 39	Sandy silt (Q1):	85 88	28 24	39° 43°	0 50	Clayey silt: MDD = 105, OM = 18%	HRC Geotechnic Consultants, 7/1/79
#12 4081 Cloverdale Ave. Tract 19051 Lot 21	Clayey fine sand:	130		30°	250	$\phi = 30^\circ$, C = 250	T.K. Engineering 8/3/78
	Sandy clay to clayey fine sand:			35°	225	$\phi = 35^\circ$, C = 225	
	Silty to clay- ey fine sand (Q1):			16°	350	$\phi = 16^\circ$, C = 350	
#13 4029 Cloverdale Ave. Tract 19051 Lot 13	Fill (af):			23°	120		Maurseth & Associates 5/28/79
	Sandy silt- stone with shale (Q1):			18°	175		
#14 3986 Cloverdale Ave. Tract 19051 Lot 1	Fill (af):	94 103	30.2 16.8			MDD = 112, OM = 13.6%, $\phi = 19^\circ$, C = 515	Chang & Associates 8/17/77
	Siltstone (Q1):						
#15 3972-78 Cloverdale Ave. Tract 19051 Lot 2, 3	Bedrock (Q1):	125		15°	560		
#16 5293 Veronica Or. Tract 17320 Lot 2	Fill (af):					$\phi = 35^\circ$, C = 60	Stone Geological Service 1/9/67
	Bedrock (Q1):					$\phi = 32.5^\circ$, C = 350	
#17 3930 Cloverdale Ave. Tract 20095 Lot 2	Siltstone (Q1):	98.4	27	30°	800	Sandy to clayey silt MDD = 115, OM = 16%	Lockwood-Singh & Associates 4/16/79
#18 5232 E1 Mirador Or. Tract 17320 Lot 28	Silt (af):					MDD = 118, OM = 13.5%, $\phi = 19^\circ$,	Action Engineering 12/18/78; 5/5/78
	Soil (Qco):					C = 320	
	Soil (Qco):					$\phi = 18^\circ$, C = 160	
	Siltstone (Q1):					$\phi = 23^\circ$, C = 770	
#19 5228 E1 Mirador Or. Tract 17320 Lot 26	Clayey to sandy silt (af):					$\phi = 22^\circ$, C = 420	Action Engineering 3/8/79

TABLE 2. (continued)
SOIL TEST DATA

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (% dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in % dry weight; angle of internal friction (ϕ) and cohesion (C, psf) sample remolded to 90% compaction (2) (3)	Source of data (4)
#20 5201 E1 Mirador Or. Tract 17320 Lot 20	Silt (af):					$\phi = 23^\circ$, C = 770	Action Engineering 11/23/78
#21 5111 Veronica Dr Tract 17007 Lot 15						Imported fill: clayey silty sand MDD = 123, OM = 11% Existing fill: MDD = 116, OM = 14%	Lockwood-Singh & Associates 1/9/78
#22 5108 Veronica Or. Tract 17007 Lot 9	Clay (Qco): Clay (af):					$\phi = 19^\circ$, C = 350 $\phi = 17^\circ$, C = 420	Action Engineering 5/3/78
(SUB-AREA 3) #23 4563 Oon Rudolfo Pl Tract 20871 Lot 71	Silt: Clayey sand: Silt (Qi):	90-92.4 110.9 90.9	12.5-13.3 8.2 13			Clayey sand: $\phi = 30^\circ$, C = 200 Silt: MDD = 104.9, OM = 13% $\phi = 34^\circ$, C = 150 Sandy silt: MDD = 101.7, OM = 13% $\phi = 31^\circ$, C = 150 Clayey sand: MDD = 117.9, OM = 9% $\phi = 33^\circ$, C = 250	Lockwood-Singh & Associates 10/6/78
#24 4500 Oon Rudolfo Pl Tract 20871 Lot 65,66	Silty sand: Sandy silt: Clayey silt with sand (Qi):	94 93 88	11.1 8.9 15.6	22° 21° 7°	200 120 730	Sandy silt: MDD = 115.5 OM = 14.3%	Baseline Consultants 10/3/78
#25 4435 Don Milagro Or. Tract 17452 Lot 55	Sandstone (Qi):			32°	200		Soils International 2/22/79
#26 4223 Oon Diablo Dr. Tract 14644 Lot 54	Sandy clay: Sandy silt: Sandy silt: Silty sand (af):	114 108 113 107	15 16 9 13			Sandy clay: MDD = 124-126 OM = 9-11% Sandy silt: MDD = 125 OM = 9%	Foundation Engineering Co. Inc., 5/25/79
#27 4121, 4127 Don Diablo Dr Tract 13644 Lot 60, 61	Fill (af):	100.1-131.9				MDD = 122 OM = 12%	Maurseth-Howe- Lockwood Associates 8/21/69, 2/71, 5/13/71
#28 4245 Don Alanis Pl. Tract 17452 Lot 17	Clayey sand: Clayey sand (Qb):	113.6 109.7	15.8 17.0	16° 21°	350 300	Clayey sand: MDD = 126.5 OM = 10.5% 90% compaction: $\phi = 24^\circ$, C = 200 Sand, medium-coarse: MDD = 128.0 OM = 10.0%	Lockwood-Singh & Associates 3/13/80

TABLE 2. (continued)
SOIL TEST DATA

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (%dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in % dry weight; angle of internal friction (ϕ) and cohesion (C, psf) of sample remolded to 90% compaction (2) (3)	Source of data (4)
#29 4131 Don Ibarra Pl. Tract 17451 Lot 33	Sand (Qb): (depth up to 20 ft.)	92-104	9-20			Moisture content increases with depth	Maurseth-Howe- Lockwood, Associates 8/1/68
#30 4114 Don Ibarra Pl. Tract 17451 Lot 55	Silty sand: Sand and gravel: Silty sand and gravel (Qb):	90 107 86	7.3 4.7 7.7			$\phi = 31^\circ$, C = 0	Baseline Consultants 9/29/78
#31 4100 Don Ibarra Pl. Tract 17451 Lot 53	Clayey sand: (2 ft. deep) Clayey sand: (3 ft. deep) (Qb)	113.7 121.7	9.9 11.5			MDD = 128.6 OM = 10% $\phi = 18.4^\circ$, C = 58D	Ralph Stone Co. 7/27/78
#32 4025 Don Ibarra Pl. Tract 17451 Lot 41	Fine to coarse sand (Qb):	99-102	11.8-13.2	28°	200		Baseline Consultants 4/10/80
#33 3901 Don Felipe Dr. Tract 14644 Lot 76	Silty clay to sand (af): Silty clay to clayey sand (Qi):	111.3- 123.2 101- 119.8	7.6-15.2 6.1-9.4			Fill up to 5 ft. depth Native up to 15 ft.	Converse Foundation Engineers 8/8/63
#34 4100, 4108 Don Luis Dr. Tract 17453 Lots 13, 14	Fill (af): Fill (af):	110 110		20° 30°	300 500		Soils Inter- national 12/22/77
#35 4119 Don Tomaso Dr. Tract 14641 Lot 30	Very fine sandstone and silty sand- stone (Qi):	100-120		25°-30°	350-400		Maurseth, Howe 4/7/66, 3/11/66
#36 4137, 4143 Don Tomaso Tract Lots 33, 34	Very fine silty sand- stone (Qi):			31° *34°	300 *120		Pacific Soils 3/10/66
#37 4275 Don Mariano Dr. Tract 17451 Lot 93	Silty sand with gravel (3 ft. depth) Silty sand: (3.5 ft. depth) (Qb)	104.0 97.9	7.7 - 7.3	25° 20°	150 250	Sand with gravel: MDD = 134, OM = 9% $\phi = 20^\circ$, C = 250 Silty sand: MDD = 126, OM = 11% $\phi = 26^\circ$, C = 250 Silty sand with gravel: MDD = 126, OM = 10% $\phi = 31^\circ$, C = 200	Lockwood-Singh & Associates 12/15/78

*Unsoaked sample

TABLE 2. (continued)
SOIL TEST DATA

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (%dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in %dry weight; angle of internal friction (ϕ) and cohesion (C, psf) of sample remolded to 90% compaction (2) (3)	Source of data (4)
#38 4312 Oon Luis Or. Tract 17451 Lot 95	Silty sand (Qb):	102.0	13.7			Silty sand: MDD = 123, OM = 12%	Lockwood-Singh 12/19/78
	Silty sand(Qb):	99.8	12.2				
	Silty sand(Qb):	100.9	13.0	24°	300	$\phi = 26^\circ$, C = 200	
	Fill (af):	102.6	3.4				
	Fill (af):	110.3	7.2				
	Sand, medium to coarse with gravel (Qb):	106	5.2	36°	100	Sand with gravel: $\phi = 35^\circ$, C = 200	
	Fill (af):	111	15.4			MDD = 120	
	Fill (af):	106	8.9			MDD = 118	
	Fill (af):	109	11.9			MDD = 118	
#39 4412 Oon Cota Pl. Tract 17451 Lot 106 (and nearby lots)	Sand (Qb):	90-113	10-22				Soils International 2/9/79
	Silty sand, clay (af):	102-113	12				
	Medium sand, (Q1):	106	9				
#40 4427 Oon Tomaso Dr. Tract 17453 Lot 35	Sandy clay: (Q1)	117.5	10.3			MDD = 127.7 OM = 9.2%	Geolabs-Westlake Village, 1978
#41 4506 Valdez Or. Tract 17454 Lot 89	Medium to coarse sand:	111.5	7.6	20°	250	Sand: MDD = 129, OM = 8%	Lockwood-Singh & Associates 2/2/79
	Medium to coarse sand:	116.4	11.7			Sandy silt: MDD = 119, OM = 12%	
	Sandy silt	104.7	10.8			Silty sand: MDD = 123, OM = 10.5%	
	Sandy silt: (depth 3.5 to 4 ft.) (Q1)	110.4	11.3			$\phi = 34^\circ$, C = 150 psf	
#42 4472 Oon Milagro Tract 17452 Lot 82	Siltstone (Q1):	86 88	22.4 22.1				Soils International 10/4/78
#43 4520 Oon Felipe Or. Tract 17455 Lot 115	Gravelly sand (af):			38°	80	MDD = 118.5 OM = 6.2%	Pacific Soils Engineering, Inc. 7/8/58
#44 4557 Don Felipe Or. Tract 17455 Lot 45	Fill (af):			17°	450	Silty sand: MDD = 120.1 OM = 12.1%	Pacific Soils Engineering, Inc. 10/9/57
						Sandy clay: MDD = 107.7 OM = 19.6%	

TABLE 2. (continued)
SOIL TEST DATA

SAMPLE LOCALITY	MATERIALS	FIELD (IN SITU) VALUES				MISCELLANEOUS DATA	REFERENCE
	Lithology (map unit) (1)	Dry density (pcf) (2)	Moisture content (%dry weight)	Angle of internal friction (ϕ) of soaked sample	Cohesion (C, psf) of soaked sample (3)	MDD=maximum dry density in pcf; OM=optimum moisture content in % dry weight; angle of internal friction (ϕ) and cohesion (C, psf) of sample remolded to 90% compaction (2) (3)	Source of data (4)
(SUB-AREA 4)							
#45 10641 Youngworth Rd. Tract 18215 Lot 31	Fine to medium-grained clayey sand (Qc):	113-117		24° 34°	300 250	Clayey sand: C = 250 ϕ = 25	Lockwood-Singh & Associates 4/8/80
#46 10689 Cranks Rd. Tract 18215 Lot 53	Weakly cemented sandstone (Qf):	97-99	13.5-15.5	16°	800		Baseline Consultants, Inc. 6/3/80
#47 10715 Cranks Rd. Tract 17565 Lot 19	Bedrock (Qf):					Silty to clayey med.-grained sand: MDD = 124 OM = 10.5% C = 100 ϕ = 28° Silty fine to coarse grained sand: MDD = 129 OM = 9.0% C = 100 ϕ = 34°	Lockwood-Singh & Associates 6/28/78
#48 10751 Cranks Rd. Tract 17066 Lot 99	Sandstone (Qf):			33°	500		Soils International 8/7/78

(1) For explanation of symbol for lithologic (rock) unit see Plate 1. Where only one unit is designated (at end of entire locality entry), all sub-entries within the entry consist of that unit.

(2) Pcf = Pounds per cubic foot.

(3) Psf = Pounds per square foot.

(4) Dates refer to dates of consultant's reports.

Note: Locality numbers of soil samples are distributed on Plate 1 (in brown) as follows:

- 1-5: Sub-Area 1
- 6-22: Sub-Area 2
- 23-44: Sub-Area 3
- 45-48: Sub-Area 4

coherent and not disordered after sliding, is more fractured and, therefore, weaker and more vulnerable to weathering and surficial sliding. In addition, the frontal slopes and headwall scarps of bedrock landslides commonly are steeper than slopes developed in terrain that has not slid; thus, the former slopes are particularly vulnerable to surficial sliding and erosion. It may be coincidental, but there has been a particularly large number of surficial slope failures in the area of the two adjacent, tentatively identified landslides traversed by Don Diablo Drive (Slope segments I and 3J₁₋₂, Plate 1). If additional areas of terrain indicated as possible landslides on Figures 7a and 7b should prove with further investigation to be bedrock landslides, their presence may help further explain the high incidence of surficial landslides along the north flank of the hills.

Older Alluvium (Qfpu)

Older alluvium consists of flood plain deposits at the very north edge of the study area. Apparently, these deposits have been very slightly uplifted in relatively recent time.

Younger Alluvium and Colluvium (Qco, Qfp, Qfpm)

Younger alluvium and colluvium consist of modern, unconsolidated and poorly sorted deposits of clay, silt, sand, and gravel. Deposits of younger alluvium and colluvium within and around the periphery of the Baldwin Hills are shown undivided on Plate 1 as a single unit (Qco). These deposits are widespread

(as alluvium) in the interior canyons of the hills from where they extend (as colluvium) up ravines, swales, and conformable slopes. Alluvial deposits reaching the mouths of canyons wash out onto the flood plain surrounding the hills as coalescing alluvial fans. These are especially common along the steep northeast flank of the hills (Photo 8). Alluvium and colluvium within and around the periphery of the hills consist principally of sand intermixed with clay, silt and gravel, varying in composition depending on the composition of the bedrock from which they are derived. For example, pockets of gravel in alluvium and colluvium are common where the source area is Culver sand or Baldwin Hills sandy gravel. Rocks of the Inglewood Formation generally yield alluvium and colluvium with a greater proportion of clay than the former two units.

Flood plain deposits (Qfp) bordering the north and west sides of the Baldwin Hills mostly were deposited by the ancient Los Angeles River system and its recent descendant, Ballona Creek. The area of the flood plain deposits was named the Ballona Plain by Tiejie (1926), who described deposits of peat, clayey sand, and boulder gravel overlying tilted Pleistocene beds, as exposed in a trench. The peat is probably a component of marshy areas (Qfpm) that can be observed on older aerial photographs and maps, including early soil maps of the area (Nelson and others, 1919).

Artificial fill (af)

Artificial fill comprises any earth material that is placed for construction purposes or any earth and non-earth material that is dumped as waste. Fills can be classified into two types: engineered fill and non-engineered fill. An engineered fill is a fill composed of earth material that is designed and placed under engineering supervision. It is compacted to a certain density and tested to verify its quality. Non-engineered fill is uncompacted fill or fill compacted without engineering control and without verification of its quality by testing.

Most of the larger artificial fills in the Baldwin Hills area were placed during residential development in the very late 1940s and the 1950s for construction of roads and accompanying building pads. Large fills also were placed in the mid to late 1940s for construction of the Baldwin Hills Reservoir. Since the 1920s, fill has been used in the Inglewood oil field for siting of roads and oil wells.

The mapping of artificial fills on Plate 1 within residential areas is based mostly on the depiction of fills in unpublished tract development maps on file with Los Angeles City and County Departments of Building and Safety and with Culver City. Fills outside of steep-sloped residential areas (Sub-areas 1 - 4) were mostly compiled from Castle (1960a, b), although not all of Castle's fills, which he mapped in great detail, were compiled for this study. The mapping of some fills on Plate 1 is based on aerial photograph interpretation.

Although no distinction between engineered and non-engineered fill is made on Plate 1, most of the fills mapped that were placed for development of residential tracts may be considered to be "engineered fill," based on compaction reports on file with the aforementioned local agencies. Some of these fills, however, have suffered settlement, apparently indicating that even though they were engineered, they may not have been properly designed or emplaced. Also, it is known that some loose material was placed on the upper parts of the sides of some fills after they were compacted—which is not proper practice. The particular problems of improperly placed fill in the vicinity of Slope segments 1C and 1H in the northwestern part of the Baldwin Hills are discussed in the section of the report entitled "Descriptions and Evaluation of Damaging Slope Failure..."

Artificial fills in residential areas are composed of material derived from the specific site of the fills or from immediately adjacent areas. Therefore, their qualities vary, depending upon the geologic unit or material from which the fill material was taken.

Geologic History*

Introduction

Around the world where the earth's crust is very stable, only minor changes in the landscape appear to have taken place in the past several million years. During this same period, however, in the Los Angeles region, which is tectonically very active, groups of hills and ranges of mountains have risen and the sea has withdrawn to the present coast from as far inland as the vicinity of today's downtown Los Angeles. Following the recession of the sea, mastodons, saber-toothed tigers, and other animals roamed the landscape, as evidenced by their remains found at the La Brea tar pits in Hancock Park, in a trench just north of the Baldwin Hills (Tiejie, 1926, p. 511), and elsewhere. It is within the context of this dynamic environment that the Baldwin Hills grew, perhaps as recently as the past 100,000-150,000 years, with other groups of hills along the northwest- to southeast-striking Newport-Inglewood zone of faults and folds (Barrows, 1974).

The Baldwin Hills lie within the Los Angeles structural basin, as defined by Yerkes and others (1965, p. A-1), which includes most of the region of Los Angeles City, adjoining cities, and Orange County. The hills also are part of the Los Angeles physiographic basin (or plain), which includes the area south of the Santa Monica Mountains and Puente Hills and north of the Palos Verdes Hills. The structural basin is the site of deposition of an immense thickness of marine sediments, especially in the past 5 to 10 million years. These sediments rest on a "basement" of igneous and metamorphic rocks. The contrast in the composition and origin between these basement rocks on opposite sides of the Newport-Inglewood structural zone implies that the Newport-Inglewood zone has had a long and significant history as a geologic structure (Barrows, 1974, p. 35-57). Basement rocks beneath the Baldwin Hills are buried by slightly more than 10,000 feet of sedimentary rocks.

Because of the complex nature of this structurally active and unstable area, with its active faults and its changing coastline, the geologic story is far from simple. Work by Rodda (1957) in the Cheviot Hills, to the north of the Baldwin Hills, Valentine and Lipps (1970) at Rancho La Brea, Bandy and Marincovich (1973) in the Baldwin Hills, and Woodard and Marcus (1976) has contributed to the following interpretation of the geologic history in the Baldwin Hills over the past few million years.

Early Pleistocene (2 to 1 million years ago or less)

The oldest rock unit exposed in the Baldwin Hills is the early Pleistocene upper part of the marine Inglewood Formation (Qi, Plate 1 and Figure 8) (California Department of Water Resources, 1964). This rock, which commonly consists of clayey siltstone and sandstone, is widespread in terrain along the north flank of the hills where there occurred numerous damaging surficial debris slides and flows in 1969, 1978, and 1980. Deposition of these sediments ceased sometime between 1 and 2 million years ago when they were apparently lifted above sea level and subjected to erosion.

*By R.B. Saul and F.H. Weber, Jr.

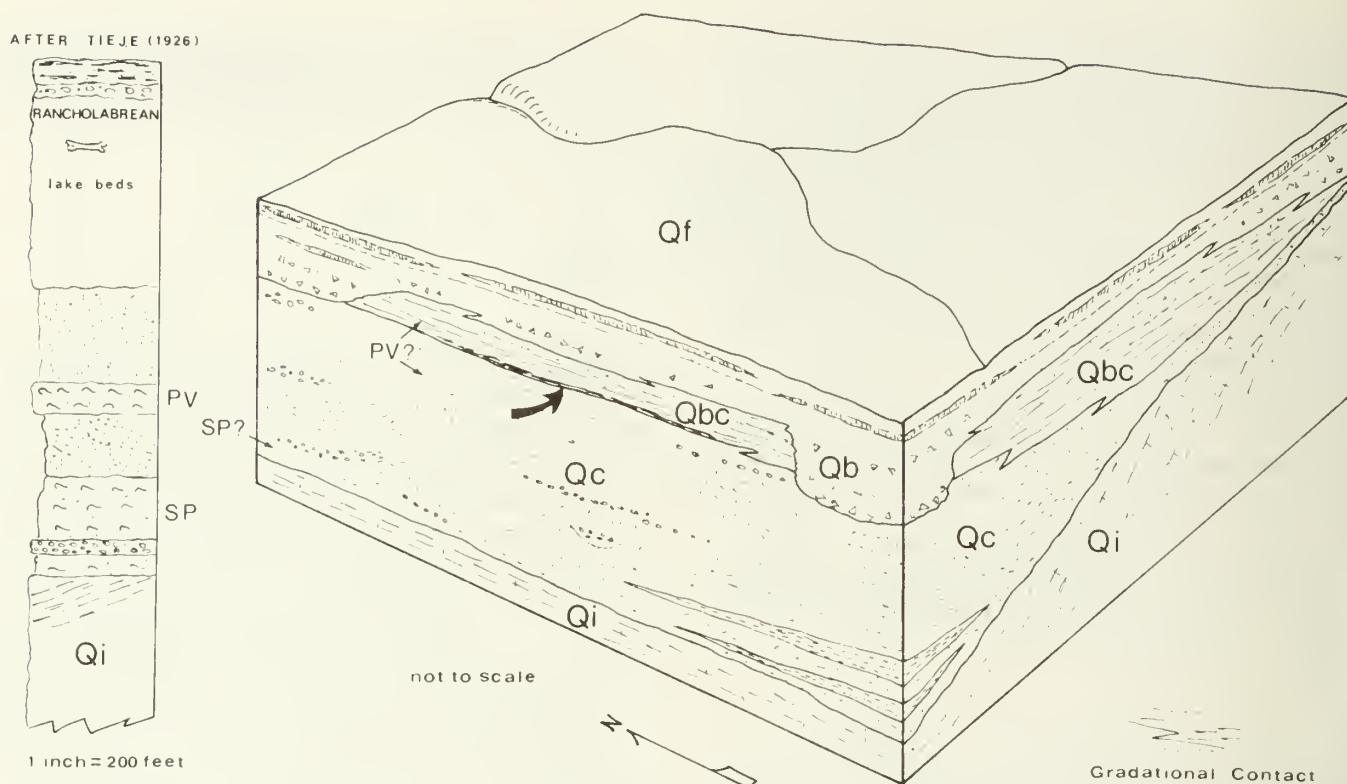


Figure 8. A block diagram, vertically exagerrated in scale, that portrays relationships among rock units exposed on the seaward slope of the Baldwin Hills uplift. The heavy arrow indicates a boy or estuarine deposit (Photo 9) at the contact between the Culver sand (Qc) and the Baldwin Hills sandy gravel (Qb). The top surface of the block represents an early stage of erosion of the coastal flood plain and the formation of soil (Qf, Fox Hills relict paleosol); this occurred following the time represented by scene B in Figure 9. The column on the left portrays rocks described by Tieje (1926) exposed in a trench just north of The Baldwin Hills. The obvious differences between Tieje's section and the rocks exposed in the hills illustrate the difficulty of lithologic correlation of coastal sediments being deposited during presumed but not often easily identified, glacially-induced changes in sea level. However, a possible correlation between San Pedro Formation (SP) and Polos Verdes Sand (PV) in Tieje's section with rock units in the Baldwin Hills is suggested in the block diagram. *Drawing by R.B. Saul.*

Late Pleistocene (1 million years or less to 10,000 years ago)

When the sea again invaded the site of the future Baldwin Hills, deposition of marine sediments resumed. The sediments that were deposited consist of cross-bedded sand and gravel similar to beach and dune deposits along the present coast. Rock fragments within the sediments were derived from the Santa Monica Mountains (pebbles and cobbles of slate and cherty shale) and the San Gabriel Mountains (pebbles and cobbles of crystalline rocks such as anorthosite and Lowe Granodiorite). The debris was carried to the area by the ancestral Los Angeles River system (which included the ancestral San Gabriel River and tributaries to that river and the lower part of the present day Los Angeles River). The rock unit that formed at that time was informally named Culver sand (Qc, Figure 8 and Plate I) for this study but may be equivalent, at least partly, to the San Pedro Sand (SP, Figure 8).

Scene A of Figure 9 shows what the landscape may have looked like perhaps 100,000 years ago. It may have been similar to Drake's Bay in northern California today, with the Santa Monica Mountains acting as a headland. The Baldwin Hills and other hills rising along the Newport-Inglewood structural zone may have constituted a chain of shoals or banks offshore from the seacoast (Yerkes and others, 1965, p. A-19). A current (shown as an arrow in Scene A) that was counter to the main southerly current may have promoted deposition resulting from erosion along the coast caused by storm waves and tidal currents. The ancestral Los Angeles River also supplied sedimentary material.

The precise time during which the Culver sand was deposited is not known because of a lack of age-diagnostic fossils in this unit in the Baldwin Hills. The upper part of the sand may be equivalent to shallow, approximately 100,000 years old marine deposits that underlie Rancho La Brea in the vicinity of Hancock Park. These latter marine deposits were dated and correlated with the Palos Verdes Sand by Valentine and Lipps (1970).

As the sea floor and land of the Los Angeles area began to rise, lagoons and marshes were created in the vicinity of the ancestral Baldwin Hills. A record of these marshes is represented in the present by exposures in the Inglewood oil field area of a thin layer of clay, rich in plant remains, that lies stratigraphically between the Culver sand and the overlying Baldwin Hills sandy gravel (Qb, Figure 8 and Plate I; also named informally for this study) (Photo 9). The Baldwin Hills sandy gravel consists of fluvial sediments deposited across a flood plain intermittently from the north and east by the Los Angeles River and its tributaries. The landscape probably was similar to Scene B shown in Figure 9.

The richly organic clay layer may be contemporaneous with a lignite deposit that contains redwood bark and other plant debris that Wissler (1943, p. 212) described as frequently encountered at the top of the San Pedro Sand in wells in the Wilmington and Rosecrans-Dominguez areas to the south of the study area. The contact between the Culver sand and Baldwin Hills sandy gravel is commonly gradational, and an apparent transitional unit between the two units was outlined roughly by R.B. Saul on the geologic map, Plate 2, in the earlier version of this report (California Division of Mines and Geology staff, 1980) and in

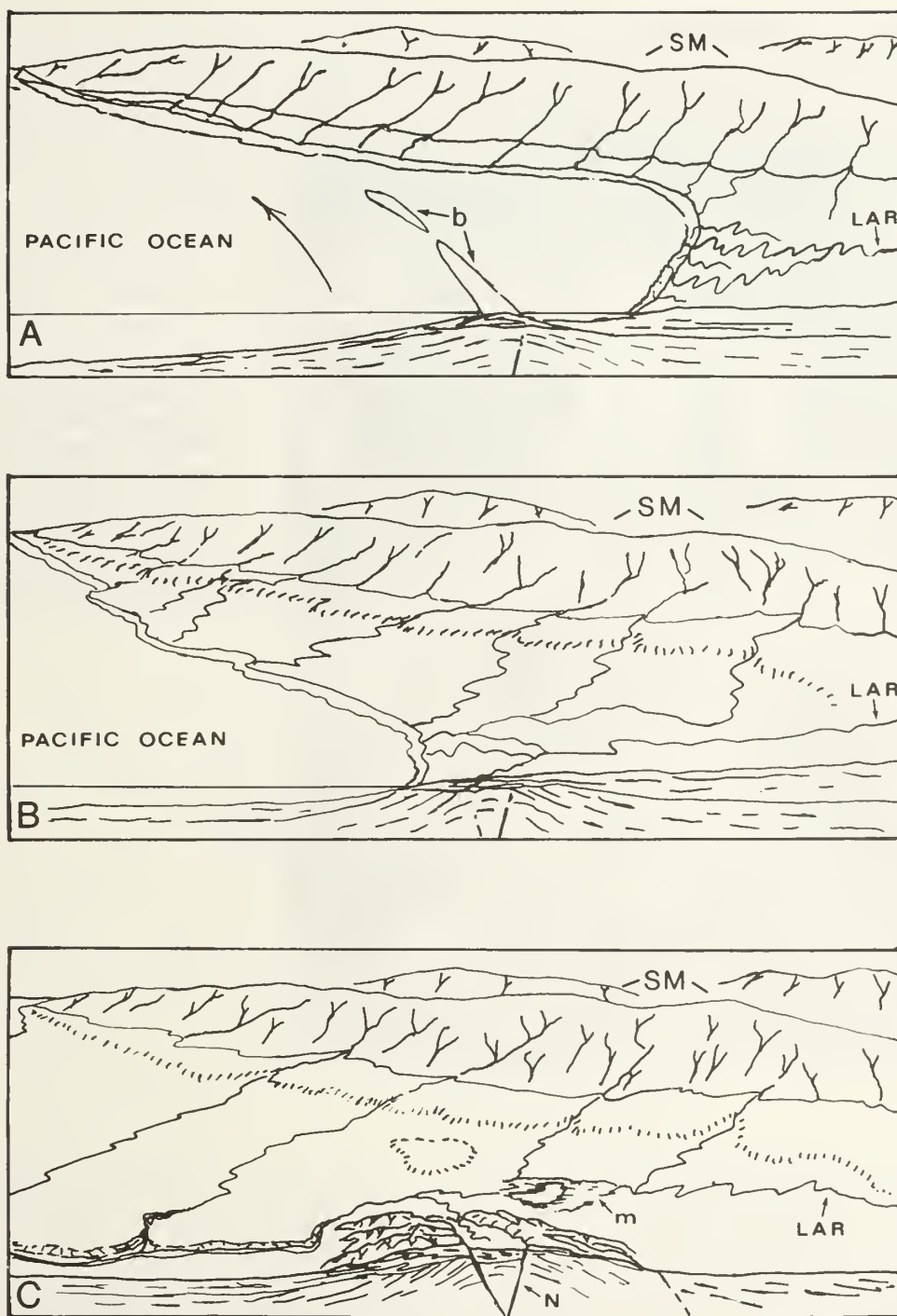


Figure 9. Generalized and hypothetical scenes illustrating oppoent historical relationships during Pleistocene time among the uplift of the Baldwin Hills, the westward retreat of the seo, and olluviation of the Baldwin Hills region by the oncostrol Los Angeles River (LAR). *Scene A*, about 100,000 years ago: the proto-Baldwin Hills (BH) ore on eroded platform copped by o barrier bor (b). The arrow indicates o possible longshore current that was counter to the principal southerly current. The counter current effected the drift of fine sediments ond, hence, buildup of the bor, but tidol currents ond storms probably were the moior ogents of erosion. *Scene B*, some 35,000 to 40,000 years ago: sediment movement by the oncostrol Los Angeles River (LAR) ond drainoge from the Sonto Monico Mountains (SM) keep poce with slow uplift of the Baldwin Hills ond other terroin along the Newport-Inglewood structural zone. *Scene C*, o rough approximation of near-historic time: o morsh (m) surrounds o shallow lobe os ground water flowing west to the seo is dommed by the uplift along the Newport-Inglewood structural zone (N). Drawings by R.B. Saul.



Photo 9. Cut adjacent to oil well west of La Cienega Boulevard, in northern Baldwin Hills. Dark layer in center of photograph is a layer of clay, 4 to 8 inches thick, that is rich in fossil plant debris. The pale colored rock unit below the clay layer is marine Culver sand (Qc, Figure 9 and Plate 1), a near-shore or beach deposit; the darker rock above the clay layer consists of silty sand which, with the clay layer, apparently is of estuarine or bay origin and is the lower, transitional part of the Baldwin Hills sandy gravel (Qb).

Figure 8 herein. This apparent transitional unit, ranging in thickness from 0 to 50 feet, extends northeastward from the general vicinity south of West Los Angeles College toward the Inglewood fault just east of La Cienega Boulevard. Clastic debris making up the Baldwin Hills sandy gravel originated mostly as fluvial deposits of the ancestral Los Angeles River, but the rock unit also contains beach pebbles derived locally by erosion from the Culver sand.

As the hills rose above the alluviated flood plain, in a terrain much like today's, a deep soil developed in the uppermost part of the Baldwin Hills sandy gravel. Because it is so resistant to erosion, the soil has been partly preserved southwest of the Inglewood fault as a relic. It was informally named Fox Hills relict paleosol (Qf, Figure 8 and Plate 1) for this study. Northeast of the Inglewood fault, the paleosol has been mostly removed by erosion. Scene B, Figure 9, shows the Baldwin Hills as they may have looked about 35,000-40,000 years ago, during deposition of the earliest nonmarine deposits at Rancho La Brea (based on work by Woodard and Marcus, 1976).

Many of the larger, pre-development landslides (Qls) shown on Plate 1 and in Figures 7a and 7b could have occurred during the period of large amounts of rainfall that accompanied cooler climates during late Pleistocene time. Stout (1977, p. 104-105) suggested that many of the larger landslides of southern California occurred during a period of generally heavy precipitation that occurred between 16,000 and 20,000 years ago.

Holocene (10,000 years ago to present)

Scene C, Figure 9, depicts the Baldwin Hills area in very recent (near-historic) time, showing the graben that has developed in the hills along the Inglewood fault (N). The figure also shows a marshy area (m) surrounding a small lake that existed just north of the hills. This marshy area persisted into historic time (Figure 10) and disappeared when the pumping of ground water began. The water stayed at the ground surface because flow to the sea through Ballona creek (the lowermost part of the ancient Los Angeles River) was impeded by barriers made up

either by impervious clay gouge of faults of the Inglewood zone or cemented gravels which extend upward into the alluvial ground—possible testimony to the recency of activity of faults in the area. The reason for this impedance of the flow of ground water is discussed by Poland and others (1959).

More testimony to the youthfulness of uplift and faulting is shown in Photo 8. This pre-development photo shows an apparent fault scarp at the base of the north flank of the Baldwin Hills, with a small alluvial fan depositing debris over the scarp. Ambiguous evidence suggesting Holocene faulting has been discovered on the Inglewood fault south of Stocker Street by Engineering Geology Consultants Inc. (1975). Tieje (1926, p. 510) describes an undeformed bed of boulder gravel just 2 to 3 feet beneath the ground surface at a locality just north of the Baldwin Hills; he states that this bed is offset 30 feet downward along the east side of a fault that strikes N. 30° W.

The behavior of the Los Angeles River system during the 1800s gives mute testimony to the dynamics of the recent geologic history of the Los Angeles area. Prior to the winter of 1823-24, for an unknown period, the river flowed westward from the south part of downtown Los Angeles, into Ballona Creek, along the west side of the Baldwin Hills and into the ocean where Marina del Rey is today (Troxell, 1942, p. 388). In the winter of 1823-24, intense flooding caused the course of the river to change so that it flowed southerly into San Pedro Bay. Since

1823-24, the river has continued to flow southerly into San Pedro Bay; only in 1861-62 and 1884 has flooding caused it to overflow into Ballona Creek.

In conclusion, the Baldwin Hills consist of soft, youthful sediments that have been uplifted along faults in relatively recent geologic time, with steep terrain cut into them by erosion. Uplift has been accompanied by earthquakes along faults, the largest of which in historic time has been the Inglewood earthquake of 1920. Shallow debris slides and flows, surficial erosion, and even bedrock landslides probably have been relatively common in this steep terrain during rainy years all through Holocene time.

Development of Grading Codes*

Introduction

Development of residential tracts in the steep-sloped, northern and western parts of the Baldwin Hills began in 1949. At that time, most of the lower parts of the hills and the areas bordering the hills were already developed residentially and commercially, and much of the west-central and south-central parts of the hills contained the Inglewood oil field which dated back to 1924. Also

*By E.Y. Hsu

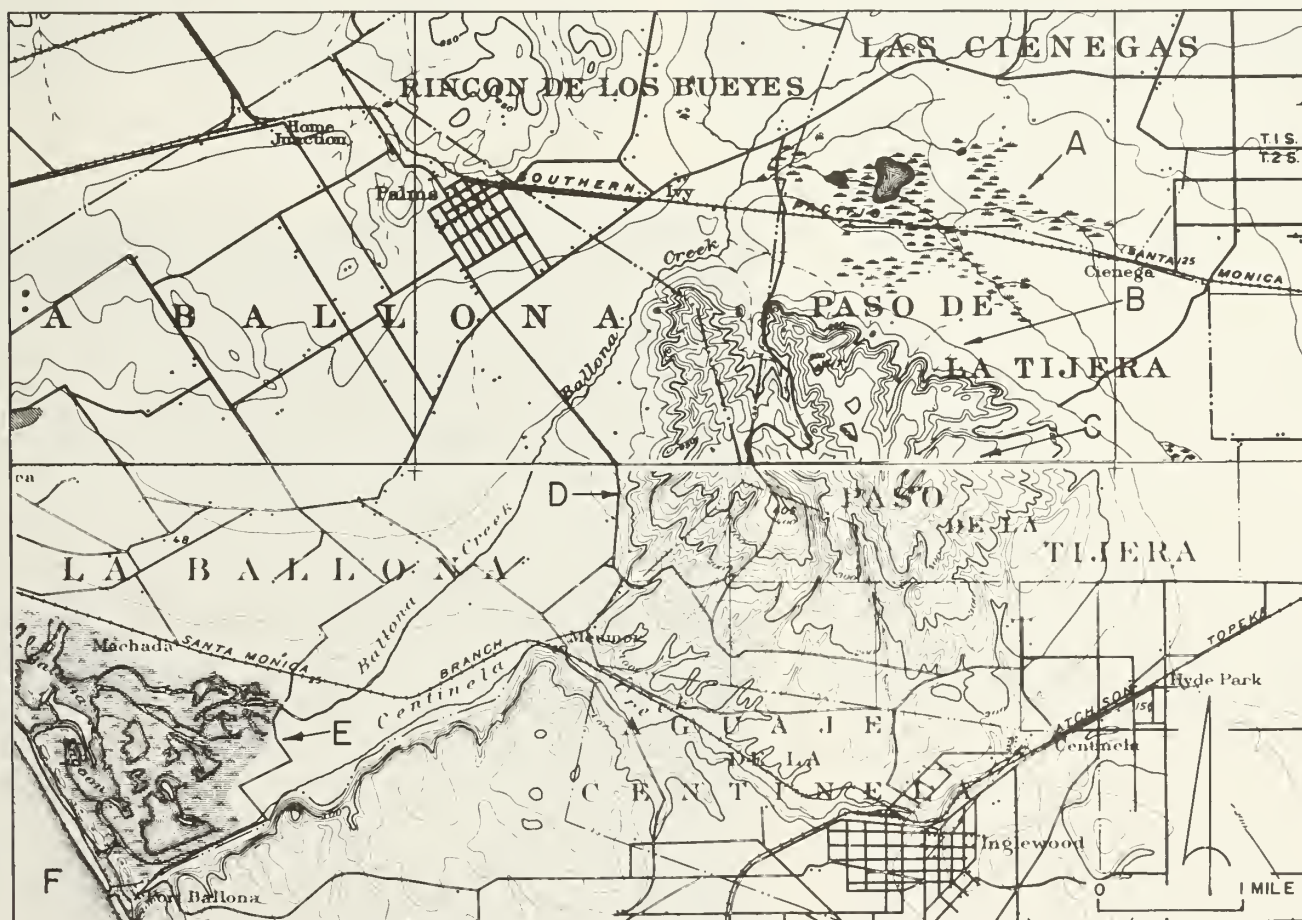


Figure 10. Port of west and southwest Los Angeles region in about 1900 showing the undeveloped Baldwin Hills. Note: A, morshy ground north of the hills; B, steep, north-northeast facing escarpment along the north flank of the hills showing streams on alluvial fans extending away from the escarpment; C, terrace-like surface of parts of the domed hills; D, steep slope bordering the flood plain of Ballona Creek; E, Ballona Lagoon, now Morino del Rey; F, Pacific Ocean. (Bose map is from U.S. Geological Survey Redondo and Sonto Monico 15-minute quodrongles, doted 1896 and 1902, respectively; contour interval 25 and 50 feet, respectively.)

in 1949, the ill-fated Baldwin Hills Reservoir was under construction. Most of the tract development in the hills was completed by 1957, although some tracts were developed in the very latest part of the 1950s and the early 1960s. Buildings still are being constructed on individual lots: for example, grading was taking place in early 1981 for construction of a large condominium complex just south of Don Lorenzo Drive between La Brea Avenue and Stocker Street.

The booming hillside development in the Baldwin Hills area in the early to mid-1950s unfortunately took place before safeguards against geological hazards were developed by local governments in the Los Angeles region with jurisdiction over matters of building and safety. By 1980, however, hillside development was regulated under stringent grading codes that were adopted incrementally beginning in 1952 by the City and County of Los Angeles and other counties and cities in southern California and by the State of California. Development of standards for grading, enacted into local ordinances, can generally be grouped into three periods: pre-1952, 1952-1963, and 1963-1980.

Pre-1952

Hillside development within the study area during the late 1940s and earliest 1950s was achieved by levelling off ridge tops and filling of the bottoms of canyons and ravines (Photo 10). By slicing off tops of ridges between canyons and using the excavated material as fill along the edges of the ridges, a street and a row of pads along each side of the street could be placed on a ridge. Adjoining the ridges, already steep natural slopes along canyon

bottoms were cut back in order to make space for a street and a row of building pads along each side of the street. Such development generally steepened already steep natural slopes at both the top and the bottom, and the development may or may not have been done with evaluation of the site condition by soil engineers and geologists. No soils reports regarding this development in the City of Los Angeles and Culver City portions of the hills are on file with those cities. However, fill compaction reports for development of most of the tracts in the two cities are on file.

During the pre-1952 period, all that was required of the developer and the grading contractor by the City and County of Los Angeles was a "fill control report" from an approved soil testing laboratory, which certified that the fill was properly compacted. The building codes of that period did not require that the principles of soil mechanics and engineering geology be utilized to ensure the future stability of slopes that were graded.

Available records on file with local departments of building and safety indicate that emplacement of artificial fill for tracts was generally done using methods similar to those of today. These methods included: (1) the removal of vegetation and trash from the natural terrain, (2) scarifying of the natural slopes in order to ensure bonding of the fills to natural material, (3) benching of natural slopes before emplacement of fill material on them, and (4) application of water to the fill material in order to obtain optimum moisture content. Fill material used for grading tracts in the Baldwin Hills apparently consisted of locally excavated materials. Fills were compacted by a sheepfoot roller to 90% of the maximum dry density of the rock material making

Photo 10. Aerial view to the west-northwest on June 2, 1951, shows grading and construction underway for single-family residences just west of the intersection of Stocker Street (S) and Don Felipe Drive (DF). The porticular cut and fill method of grading used in development resulted in many steep unstable slopes of the natural topography that were made even steeper, and thus, even more unstable. (Additional streets: DD, Don Dioble Drive; DL, Don Luis Drive; DT, Don Tomoso Drive; LB, Lo Brea Avenue.) Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.



up the fill. Recent structural damage resulting from sagging and settlement of fills in the Baldwin Hills suggests, however, that some fills may not have been uniformly and adequately compacted. In addition, slope failures originating in fill slopes and water seepage from the fills indicate that proper subdrains were not constructed.

Prior to 1952, apparently very little attention during design and grading was paid to the future stability of the slopes, as evidenced by the lack of properly designed bench and slope drains and the extreme steepness of both cut and fill slopes (Photo 11). The following statement by a civil engineer in a letter in 1958 to the Department of Building and Safety of the City of Los Angeles reflects on the inadequacy of grading control at that time: "It was a common practice in the 1950s for additional uncompacted fill to be dumped over the rear compacted fill slope...." It is also known that over-sized blocks of waste concrete were disposed of in a large area at the base of a compacted fill for a residential tract in the Los Angeles portion of the Baldwin Hills. Over-sized debris is acceptable today only in controlled circumstances. It seems apparent that, before 1952, developers and grading contractors could legally design and grade slopes as they chose.

1952 - 1963

As a result of the heavy rains of January 13-18, 1952, which caused \$7.5 million of property damage in hillside areas of the City of Los Angeles alone, the City enacted in that year the first ordinance in California to control the development and grading of hilly and mountainous terrain. This ordinance, which placed administration of its grading code provisions under the City Department of Building and Safety, established a system of mandatory permits, inspections, and certification for grading. The ordinance was flawed, however, in that it left it to the judgment of a City inspector to decide whether the developer or contractor required a soils study and accompanying report to evaluate stability factors of the site (Photo 13). Similarly, the need for a geological appraisal was left to the discretion of an inspector or a department engineer. More often than not, the department inspectors and engineers did not have sufficient training or experience to recognize the potential geologic hazards of a tract site.

The importance of geologic evaluation of site stability was not fully appreciated in the Los Angeles region until 1956 when the

City of Los Angeles established a "Geologic Hazard Committee" consisting of civil and soils engineers, engineering geologists, persons from construction industries, and government officials. This committee recognized that to provide for the development of hillsides the City needed a series of large scale geologic maps covering hillside terrain, and, also, an ordinance requiring a geologic report to accompany the findings of a soil engineer for any proposed development in hillside terrain. As a result of subsequent action by the City, geologists and soil engineers for the developer, as well as technical staff of the City Department of Building and Safety, including geologists and inspectors, became participants in the decision-making process concerning the soils and geologic conditions of new development in hilly terrain. In addition, City geologists prepared a series of large-scale geologic maps that covered the City-portion of the Santa Monica Mountains. These maps have been used by the staff of the City Department of Building and Safety in evaluating geologic reports submitted by the developer. The committee also advised the City on the general problems of engineering geology and geologic hazards. In 1958 the City of Los Angeles also established a "Board of Qualification for Engineering Geologists" and thus was able to provide the public with a list of geologists that were deemed qualified by the Board.

During the period from 1956 to 1960, a geologic evaluation of a tract site was generally required by the City before it issued grading permits. However, no minimum guidelines as to how the evaluation should be made and how the accompanying report should be written were established. Since the code requirements for grading plans were vague, it was possible for the contractor or developer to submit a biased geologic and soils report. The code proved inadequate also because it did not require technical supervision of the grading by the design civil engineer to assure that the grading was done in conformance with his recommendations; the grading still was supervised wholly by the grading contractor. Also, geologic services were only rarely continued by contractors during the grading even though geologists could recognize hidden potential hazards that might be uncovered and could assist in carrying out the corrective work needed.

In 1960, the City of Los Angeles adopted a guide for geologic investigations that had been recommended by its Board of Qualification for Engineering Geologists. Also in 1960, the County of Los Angeles established a qualifications board similar to the City board and adopted similar guidelines for geologic reports.



Photo 11. Aerial view south taken on September 15, 1952, shows: A, that grading was completed and construction of houses was taking place along Weatherford Drive; B, that construction of houses along Brushstun Street and Alladin Street was completed (grading had started in 1946), but that grading far houses along the uppermost part of the slope, an Glenford Street, had not started; C, that grading along Claverdale Avenue had not started; D, that grading was underway for completion of La Cienega Boulevard through the Baldwin Hills; E, approximate location of the Inglewood fault; and F, the then recently completed Baldwin Hills Reservoir. Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.

1963 - 1980

Damage resulting from the heavy rains of the winter of 1961-62 prompted the City of Los Angeles and the City of Glendale to legislate ordinances in 1963 that combined soils engineering and engineering geology investigations. These ordinances specified that building permits were to be approved only after final engineering reports were prepared which certified the stability of sites. In addition, before final approval was made, the City had to receive a final certification from the supervising civil engineers for the development that all lot drainage systems, improved drains, plan elevations, erosion prevention methods, and stabilization measures were completed as depicted on the approved grading plans. Thus, in 1963 the full participation of professionals in the City of Los Angeles was ensured. Also by that time, some local governments had hired geologists to enforce the geologic aspects of grading codes.

The Uniform Building Code (UBC), which was first enacted in 1927 by the International Conference of Building Officials, was modified in the 1950s and 1960s to accommodate the need for improved grading practices. In 1963, with assistance from the Association of Engineering Geologists (AEG), Chapter 70, which describes specifications for grading, was added to the code. Chapter 70 and Chapter 29 (which deals with regulations on excavation, foundation, and retaining walls) provided local government agencies with specifications with which to regulate hillside development. These chapters provide local building and safety officials and their staffs with a means to require preliminary investigations of tract sites by qualified soils engineers and engineering geologists, to require the developer to retain the services of both disciplines during construction, and to certify the stability of the building site before issuance of building permits. Chapter 70 also specifies that a civil engineer supervise grading during construction in coordination with an engineering geologist and a soils engineer. In 1974, the State of California administratively mandated that local governments utilize Chapter 70 to regulate grading if they do not have similar or more stringent regulations. Culver City utilizes Chapter 70 to regulate grading. The City and County of Los Angeles have their own, more stringent requirements.

GENERAL FEATURES OF SLOPE FAILURE, AND ADDITIONAL GEOLOGIC HAZARDS*

Landslides and Erosion

Since their development in the very late 1940s and 1950s, residential areas of the Baldwin Hills have suffered damage from the effects of landsliding and erosion caused by heavy sustained rainfall in 1969, 1978, 1980, and other years. Although in 1978 the greatest damage from the rains in the southwest Los Angeles region occurred in the Baldwin Hills, lesser damage occurred about 2 miles to the northwest in the Cheviot Hills-Castle Heights area and to the west in the Mar Vista area (Weber and others, 1978). Winter storms also have caused substantial and widespread damage slightly farther away to the north in the Santa Monica Mountains (Campbell, 1975; McGill, *in* U.S. Army Engineer District and U.S. Geological Survey, 1976; Weber and others, 1978), and to the south in the Palos Verdes Hills (Jahns, 1958; Cleveland, 1976). In 1980, rains caused extensive damage to the east of the Baldwin Hills in the Monterey Park area of the Repetto Hills (Weber, 1980). Damaging landslides have been and are expected to continue to be a major geologic hazard in California (Alfors and others, 1973).

Damage from landsliding and erosion in the Baldwin Hills has occurred to the slopes themselves, to retaining walls and other structures built at the tops and bottoms of slopes, and to residences, swimming pools and other improvements adjoining slopes, as shown on Plate 1. Individual damaging slope failures are described in detail in a subsequent section of this report.

Most commonly, slope failure in the Baldwin Hills has consisted of surficial landslides and erosion. Surficial landslides comprise shallow slumps and debris slides and flows, including soil slips, that consist of water-bearing mixtures of slope material derived from the surficial mantle of soil, colluvium (soil and rock material transported downslope), and vegetation that develops on bedrock or fill. Such surficial failures generally are less than 5 to 10 feet in depth. Surficial landslides nearly always occur at the height of sustained, heavy rainfall when the terrain is thoroughly saturated. They may occur in natural slopes and in cut and fill slopes, or complexes of these types of slopes. Surficial landslides may move relatively slowly (slide or ooze) down slope or they may move rapidly (flow) at high speeds. High-speed flows in the Santa Monica Mountains and elsewhere in southern California commonly have struck residences at the bottoms of slopes, and, in some instances, caused the death of occupants. No one in the Baldwin Hills, however, has been killed or apparently seriously injured by a debris flow.

Surficial landslides are more apt to occur in steeper slopes (30-35° or more) and are less apt to occur in gentler slopes (20-25° or less). In a study of the destructive effects in the Santa Monica Mountains of the rainfall of January 1969, Campbell (1975) discovered that surficial slides and flows occurred most commonly in slopes with angles between 26° and 45° and rarely in slopes with angles less than 18°.

Erosional features include rilling, where water is spread out while flowing down a slope, and gullying, where the flow is channelled. Erosion is particularly a problem where a high volume of water flows rapidly down slopes denuded essentially to bedrock by previous slides and flows that have removed the surficial mantle of soil and colluvium.

Deep-seated landsliding has been a serious problem at only a few localities in the Baldwin Hills since their development (see Slope segment 1A). However, well-identified, probable and possible pre-development deep-seated landslides have been mapped in the hills during this study (Plate 1 and Figures 7a and 7b). This suggests that large deep-seated landslides could be reactivated, possibly by strong seismic shaking when the ground has been saturated by rain water, and cause substantial damage.

Most of the geologic units of the Baldwin Hills shown on Plate 1 are susceptible to slope failure; certain generalizations, however, can be made relative to the circumstances of failure depending on which geologic units underlie a slope and which additional geologic factors exist. For example, the Inglewood Formation (Qi) is probably the unit in the hills most susceptible to surficial slides and flows because, even though it is relatively well indurated, it contains sufficient clay to yield clayey soils and slope wash. Because the Inglewood Formation underlies the lower parts of so many of the steep slopes in the north part of the Baldwin Hills (Sub-areas 1-3), these slopes seem to be particularly vulnerable to surficial slides (including soil slips) and debris flows. In contrast to the Inglewood Formation, the Culver sand (Qc) consists mostly of relatively soft sand, and slopes underlain by this unit are very susceptible to erosion. Where the Baldwin Hills sandy gravel (Qb) overlies the Inglewood Formation, rain water may percolate down through the sandy gravel and out onto slopes at the top of the less permeable Inglewood Formation, exacerbating the potential for slope failure, as suggested by J.A. Treiman (see discussion of Slope segment 2E in a subsequent section of the report). Likewise, water percolating

*By F.H. Weber, Jr.

down through improperly emplaced fill (af), and out onto a slope at the base of the fill, creates an environment for slope failure (Slope segments 2H, 2-0, and 3V).

There may also be a relationship between slope failure and the presence of faults, because clay gouge commonly occurs along fault planes, even in faults that have not been active for thousands of years. Thus, slope failures can occur where this gouge, along with rock weakened by faulting on either side of the fault, is exposed in the slope (see discussion of Slope segments 1A, 2F and 2P). Another possible geologic factor in the occurrence of surficial landslides in the Baldwin Hills involves probable large, ancient deep-seated landslides (QIs) which consist of rock weakened by fracturing. Natural slopes developed on landslides are particularly vulnerable to surficial failures. Thus, it may be coincidental or not that slopes graded in probable ancient landslides in the northeastern part of the Baldwin Hills have seemingly suffered a greater incidence of slope failure than slopes graded in adjacent rocks that have not slid (Slope segments 3I and 3J₁₋₂).

The Baldwin Hills area has an especially severe slope-stability problem because residential tracts were developed there before effective grading codes were enacted by local governments responsible for the safety of dwellings in the hills (Association of Engineering Geologists, 1965; Scullin, 1966; separate section herein). Slopes were graded too steeply and fills commonly were not emplaced properly. This is also a problem elsewhere in southern California where failures are commonly associated with older development (Slosson and Krohn, 1978).

Additional reasons for the large number of slope failures in the Baldwin Hills involving surficial landslides and erosion is that property owners at the tops of slopes allow rain water to flow over the edges of those slopes rather than to direct the flow to the street. Also, slopes deteriorate because of improper planting and a lack of maintenance of drains and vegetation, and because of the digging of gophers.

Fill Settlement

A geologic hazard in the Baldwin Hills that does not always involve slope failure is fill settlement. This occurs where a fill has not been properly emplaced, generally meaning that it has not been properly compacted. Also, the fill material could have included trash or vegetational debris. Improper design and compaction of a fill may allow water to percolate down through it, increasing the chance for settlement. Additionally, improper design and compaction may lead to failure of a slope on the fill or a slope directly below the fill slope—where water may percolate out. Fill settlement is a problem in many areas of the hills (especially see discussion under Slope segment 2M; also Slope segments 1D, 2G, and 3L).

Seismic Hazards, Including Potential for Slope Failures and Fill Settlement Caused by Ground Shaking

The youthfulness of movement along the Inglewood fault is expressed by a well-developed scarp that lies along the east side of the previously described graben in the central Baldwin Hills. This scarp extends almost continuously south-southeasterly from La Cienega Boulevard to about Stocker Street, where the Inglewood fault apparently is displaced slightly to the northeast by a series of northeast-trending faults (Plate 1). The fault and accompanying scarp continue south-southeasterly to beyond the south edge of the study area. Because geologic investigations (Engineering Geology Consultants, Inc., 1975) have indicated

that Holocene materials have been displaced at the ground surface along the Inglewood fault and certain other faults of the Baldwin Hills-Inglewood region, the faults are considered to be capable of rupturing the ground during moderate to large earthquakes and have been included in "special studies zones" by the State of California (Hart, 1980), as mandated by the Alquist-Priolo Special Studies Zones Act (Figure 11). Castle (1960a; and Figure 11 and Plate 1 herein) shows the Inglewood fault to be offset by northeast-trending faults in the general vicinity of where it is crossed by Stocker Street. Unpublished mapping and other research by Chevron U.S.A. Inc. indicates, however, that faults splay or branch from the Inglewood fault in the vicinity of Stocker Street, but that the fault is essentially throughgoing in the present study area (R.C. Erickson, Chevron U.S.A. Inc., personal communication, 1981). There is no evidence of surface faulting caused by historic earthquakes along the Inglewood or other faults in the study area.

Damaging earthquakes have occurred along the Newport-Inglewood structural zone in historic time, but not in the study area (Barrows, 1974). The closest of these occurred on June 21, 1920, probably on the Inglewood fault, and surely within the Newport-Inglewood structural zone. The effects were particularly damaging in the City of Inglewood's business district (Photo 12) because of the nearness of its predominantly unreinforced, early 1900s masonry construction to the earthquake's epicenter (Taber, 1920; Barrows, 1974, p. 63-64). The magnitude of the Inglewood earthquake was calculated later by Richter (1970) at 4.9; the earthquake may have been damaging locally, even though its magnitude was not large, because it apparently occurred at a relatively shallow depth. This shallowness is also suggested because small earthquakes in recent years in the area have occurred at relatively shallow depths of 3 to 5 miles (based on the work of Teng and others, 1973 and 1978).

Ground shaking during the Inglewood earthquake was reported by Taber (1920) to have resulted in some ground effects (including lurch cracks) caused by liquefaction in the flood plains of Ballona and Centinella creeks, which include the southwest corner of the present study area. The Baldwin Hills themselves were undeveloped at the time of the Inglewood earthquake, but small, surficial landslides, although unrecorded, may have been triggered by seismic shaking in the steepest terrain. Both surficial and bedrock landslides in the hills could be triggered by strong ground shaking caused by future earthquakes, especially during rainy periods when the ground is saturated.

A much larger earthquake, the Long Beach earthquake, magnitude 6.3, occurred along the Newport-Inglewood structural zone offshore from Huntington Beach on March 10, 1933, causing the deaths of more than 100 persons and heavy destruction in the Long Beach-Compton area (Barrows, 1973, 1974). But the effects of this earthquake apparently were not experienced in the Baldwin Hills area.

Surficial landslides and reactivation of large, deep-seated landslides were caused by severe ground shaking during the February 9, 1971 San Fernando earthquake (Morton, 1975). Most of these landslides were in very sparsely developed foothills of the San Gabriel Mountains north of the western San Fernando Valley. Even though the landslides were relatively widespread, the ground was nearly dry; if the ground had been saturated by rainfall, landsliding could have been much more severe. The results of possible future, severe ground shaking in the Baldwin Hills could be similar to what happened in the hills north of San Fernando. It is possible that larger, deep-seated landslides could be activated, causing severe property damage, especially if the ground is saturated following prolonged rainfall. If the ground

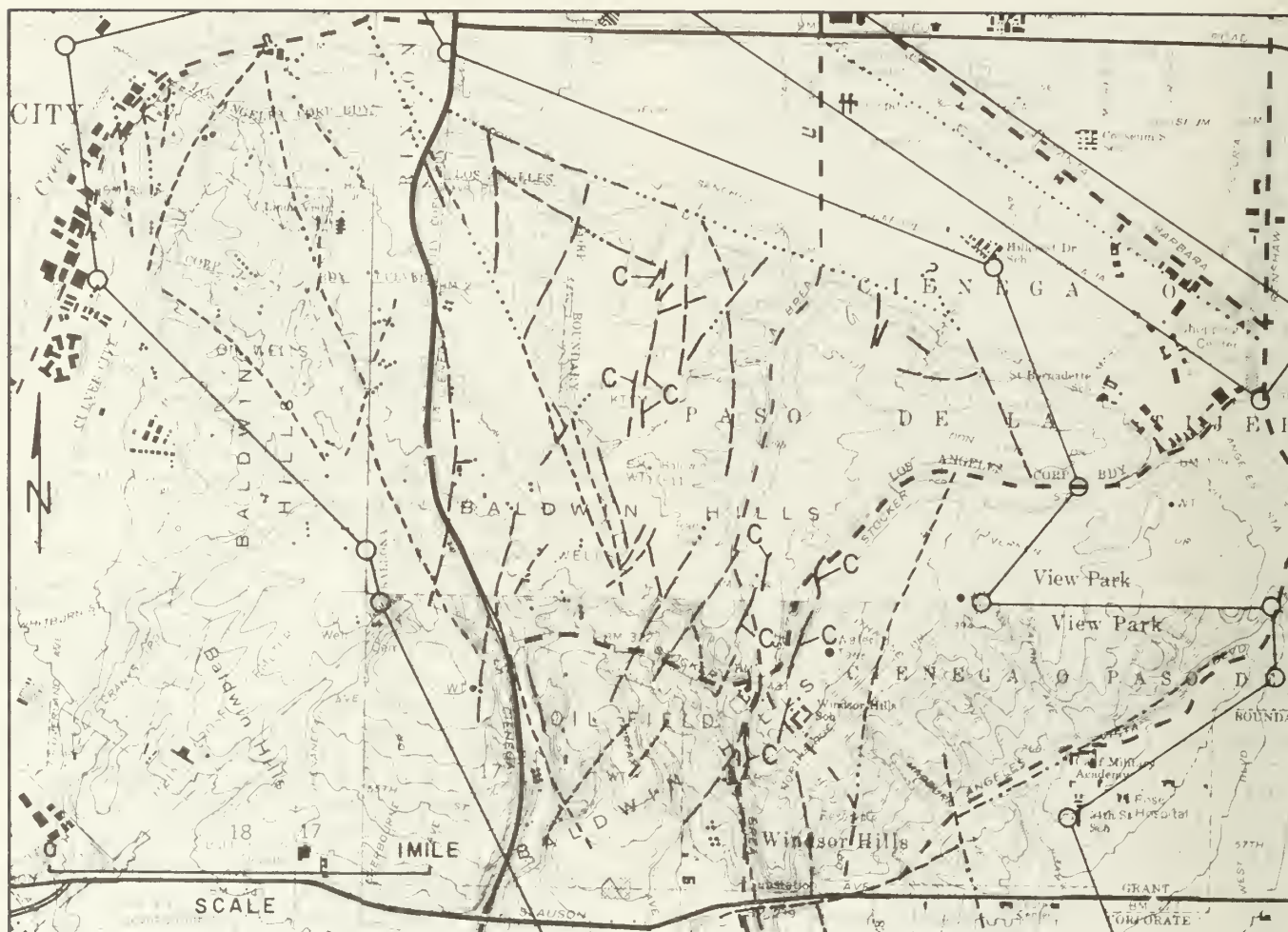


Figure 11. Outline of "special studies zone" for the mitigation of fault-rupture hazard associated with the Newport-Inglewood fault zone in the Baldwin Hills area. Data from maps of the Beverly Hills, Hollywood, and Inglewood quadrangles showing boundaries of special studies zones, prepared by California Division of Mines and Geology. Symbol "C" indicates that there is evidence for possible Holocene fault creep. Depiction of faults is mainly from Costle (1960a). For information relative to special requirements for construction within fault hazard zones, see report by Hort (1980).



Photo 12. View of damage in Inglewood caused by the 1920 Inglewood earthquake. Photograph is from a report on the earthquake by Tober (1920).

were to be saturated, fill slumps, and settlement also could be common.

Recent Surface Movements

The features of recent surface deformation in the Baldwin Hills are described in detail by Castle and Yerkes (1976). A briefer discussion is provided by Barrows (1974, p. 28-29). Additional references to the subject are listed in "References Cited" by Castle and Yerkes (1976).

Surface deformation in the Baldwin Hills, which consists of differential subsidence (downwarping), horizontal displacements and surface rupturing, has been monitored since 1939 (Castle and Yerkes, 1976, p. 1). Differential subsidence has taken place within a northwest-trending, oval-shaped subsidence bowl in the western part of the study area, largely over the Inglewood oil field (Castle and Yerkes, 1976, Plate 4), which lies southwest of the northwest-trending Inglewood fault (Plate 1, herein). Maximum measured subsidence of 5.67 feet between 1911 and 1963 occurred at bench mark P.B.M. 122, according to Castle and Yerkes (1976, p. 1 and 88). This bench mark is just east of La Cienega Boulevard, about 2,000 feet north of Stocker Street, and just east of the center of the subsidence bowl. Subsidence also has been relatively substantial in the vicinity of the intersection of La Brea Avenue, Stocker Street, and Overhill Drive. Horizontal movements of the ground surface toward the center of the subsidence bowl accompanied subsidence. Between 1936 and 1963 these movements totaled about 2.5 feet at a point just south of Baldwin Hills Reservoir, as interpreted from Plate 4 of Castle and Yerkes (1976). The effects of subsidence apparently gradually die out within about a half mile northeast of the Inglewood fault.

From the time the discovery well for the Inglewood field, "Los Angeles Investment" No. 1, was completed by Standard Oil Company on September 24, 1924 (Driver, 1944, p. 306) until January 1, 1974, nearly 50 years later, the field yielded 293 million barrels of oil and 235 million cubic feet of gas (California Division of Oil and Gas, 1974). By 1963, the field also had yielded 374,699,000 barrels of water (Castle and Yerkes, 1976, p. 89). Deepest production for the field now comes from a depth of about 9,000 feet in the City of Inglewood zone. This production is from marine sedimentary rocks of the Puente Formation, of late Miocene age, which lies above the crystalline basement floor. This floor lies at depths greater than 10,000 feet in the study area.

The principal cause of subsidence in the Baldwin Hills was the withdrawal of oil, water and gas, according to Castle and Yerkes (1976, p. 89). However, according to R.A. Ybarra, Long Beach District Deputy of California Division of Oil and Gas,

It has never been determined positively whether the subsidence in the Inglewood field was due, entirely or in part to fluid withdrawal; or whether it was due to natural earth movements, or both (Informal written communication to the Division of Mines and Geology, October 1980).

Water flooding to increase oil field production began on a serious basis in 1957, as reported by Castle and Yerkes (1976, p. 89). Water flooding is a process by which large amounts of water are pumped into the reservoir rocks of relatively depleted oil fields, forcing additional oil out of the rocks and hence increasing production. Water flooding was initially confined to the Vickers Zone in the east block of the oil field and was started in the west block in 1962. A sharp deceleration of subsidence in the east block of the field occurred when full-scale water flooding was initiated there (Castle and Yerkes, 1976, p. 1). No apparent cause and effect relationship exists between surface movements (differ-

ential subsidence and horizontal displacements) and slope failure. Most of the damaging slope failures that have occurred in the Baldwin Hills in 1978, 1980, and other years have taken place in areas not affected by subsidence or where it has been very minimal.

Accompanying subsidence was the development of lengthy surface cracks (referred to as "earth cracks" by California Department of Water Resources, 1964). These cracks, first identified at least as early as 1957, disrupt and offset natural ground and fill as well as streets, sidewalks, and buildings. The cracks occur almost entirely east of the Inglewood fault where they mostly strike north-northeast as shown on Plate 1, herein. Movement along the cracks mostly has been vertical, and mostly down along the sides toward the area of subsidence; cumulative vertical displacement along them is as much as 6 to 7 inches, according to Castle and Yerkes (1976, p. 89). Because oil well casings have been ruptured down-dip along some of the cracks, it is known that they extend to depths greater than 1,000 feet (Castle and Yerkes, 1976, p. 89). Most of the earth cracks occur along, or in the vicinity of, known faults that have been mapped at the ground surface and hence the cracks apparently represent the surface manifestations of non-seismic movement along pre-existing fault planes in the oil field area. Castle and Yerkes (1976, p. 89) state that

Displacements along the earth cracks seem to have been characterized by more or less episodic but continuous creep or small, discrete jumps. A probable exception to this generalization was the several inches of differential movement that took place along a crack through the floor of the Baldwin Hills reservoir in December 14, 1963.

The dam failed that day and flooded the narrow confines of the canyon below, which contains part of Cloverdale Avenue (Photo 13). Eight houses along the east side of the canyon were washed off their foundations. The flood also damaged additional houses along Cloverdale Avenue and in the Village Green and other areas of the flatland north of the canyon. The flood killed five persons and caused \$15 million in damage (California Department of Water Resources, 1964). All but the most southerly of the houses washed off their foundations were later rebuilt. The site of the former reservoir is the most northeasterly part of a planned future county regional park that is designed also to encompass the Inglewood oil field area ultimately.

The majority of the earth cracks, as compiled from Castle (1960a) and Castle and Yerkes (1976, Plate 2), are plotted herein on Plate 1. This map shows that most of the cracks occur in two areas: the largest number are in the vicinity of the intersection of La Brea Avenue, Stocker Street, and Overhill Drive; the second group occurs along the base of the north-trending canyon that contains the site of the Baldwin Hills Dam and Reservoir and houses along Cloverdale Avenue at the north edge of the hills; in addition, a single line of cracks extends through the site of Linda Vista School, west of La Cienega Boulevard.

None of the earth cracks plotted on Plate 1 are in the vicinity of slopes that failed during the 1978 or 1980 rains and caused damage to residential property. The only crack that occurs in the vicinity of a slope failure is the most easterly crack in the study area as shown on Plate 1. This north-northeast trending crack crosses a slope consisting partly of fill and partly of Baldwin Hills sandy gravel on the east side of Stocker Street, just north of the intersection of Stocker Street, La Brea Avenue, and Overhill Drive. The slope, which borders a park on the west, was slightly damaged by the 1978 rains. No other slope failure seems even remotely associated with the major earth cracks, as is apparent on Plate 1.



Photo 13. Aerial view north showing scene along Cloverdale Avenue after the flood on December 14, 1963, caused by rupturing of Baldwin Hills Reservoir Dam. The force of the water flowing down-canyon tore houses from the building pads shown vacant along the east side of the canyon. Houses were rebuilt on all but the more southern pads. The steep slopes behind the new houses, and houses on the west side of the street, yielded numerous damaging slope failures in 1978. (Localities 29-42, Sub-area 2, Plate 1 and Table 3b.) Photograph is from the Spence Collection, Department of Geography, University of California, Los Angeles.

DETAILED DESCRIPTION AND EVALUATION OF DAMAGING SLOPE FAILURES THAT HAVE OCCURRED IN THE BALDWIN HILLS IN 1978, 1980, AND OTHER YEARS*

Introduction

The study area was divided into six sub-areas for the purpose of field investigation, description, and evaluation of damaging slope failures (Figure 12 and Plate 1). The principal area of damage in the Baldwin Hills in 1978 extends from La Cienega Boulevard on the west to Stocker Street on the east and includes the steepest part of the north flank of the hills. This area constitutes Sub-areas 2 and 3 shown on Figure 12. Sub-area 2 extends from La Cienega Boulevard to La Brea Avenue and includes residences on Cloverdale Avenue, Terrazo Drive, Weatherford Drive, and other streets. Sub-area 3 lies east of La Brea Avenue within a triangle formed by the north edge of the hills, La Brea Avenue, and Stocker Street. Numerous properties containing apartment buildings along Don Tomaso Drive (which borders Stocker Street) were damaged, and many properties containing single-family residences along Don Diablo Drive and other streets were damaged. Sub-areas 2 and 3 mostly are within the City of Los Angeles, but they include a small amount of Los Angeles County territory on the west edge of Sub-area 2 and the east edge of Sub-area 3. Sub-area 2 was investigated, described, and evaluated by J.A. Treiman; Sub-area 3 was investigated, described, and evaluated by E.Y. Hsu and S.S. Tan.

The northwestern corner of the Baldwin Hills constitutes Sub-area 1. This sub-area includes portions of Culver City and Los Angeles City and County. It includes both residential and commercial property damaged by slope failure. It was investigated by Treiman. Sub-area 4 includes the southwestern part of the hills within the study area. It was investigated by Hsu and Tan. The sub-area consists of a residential portion of Culver City. Sub-area 5 includes the west-central part of the hills which mostly is developed as the major part of the Inglewood oil field. The investigation for this sub-area was made by R.B. Saul, with F.H. Weber, Jr. assisting mainly in preparation of the description. Sub-area 6 includes the southern and southeastern parts of the study area, within the Los Angeles County communities of View Park, Windsor Hills, and Ladera Heights. The sub-area was investigated and described by Hsu, Tan, and Weber.

In the descriptions and discussions of slope failure that follow, Sub-areas 1 to 4 are divided into individual slope segments. Each slope segment consists of a single slope except in some sub-areas (especially Sub-area 1) where several slopes are grouped together for the convenience of discussion. The problems of entire slopes or slope segments are described and discussed together because individual properties on a slope share common problems, and therefore, it is most economical and most efficient to stabilize entire slopes or slope segments rather than just the portion of a slope that covers a single property.

The way to determine where a particular property in the Baldwin Hills fits into the discussions that follow is to find its location on Plate 1 (in the pocket, herein). Each property in Sub-areas 1-4 is included within a specific slope segment (1A through 4J, numbered-lettered and outlined in green). The general area involving each property in Sub-areas 1-4 is discussed in Tables 3a-d (in pocket) and in the text that follows under the pertinent slope segment or sub-slope segment (shown in the text and on Plate 1 in sub-script numbers). Additionally, many individual properties or groups of properties which are damaged are

identified on Plate 1 by a particular locality (from 1-89, number within a circle in red); individual addresses or groupings of addresses of properties described are listed under the pertinent slope segment and slope failure locality in Tables 3a-d. Most addresses of damaged properties are also listed in Appendix II. Localities shown in brown on Plate 1 are sites where soil or rock samples have been taken and their engineering properties measured; these data are shown in Table 2, herein, and are discussed under the pertinent slope segment in the text. Slope failure localities within each slope segment in Sub-areas 1-4 are shown in parentheses at the end of each segment discussion. Localities 90-98, which are not tabulated, are described under the discussions for Sub-areas 5 and 6.

Sub-Area 1 - Northwestern Area* (Culver City 90230 and Los Angeles City and County 90016) (Slope failure localities 1-8)

Introduction and Summary

Sub-area 1 comprises the northwestern portion of the Baldwin Hills, bounded roughly on the north and west by Ballona Creek, on the east by La Cienega Boulevard, and on the south by the Inglewood oil field (Figure 12 and Plate 1). The sub-area has been under residential and commercial development mainly since the late 1940s although a few individual houses have been there since the earlier part of the century. Most of the residential development in Sub-area 1 is in the Culver City portion but some residential development has taken place in the Los Angeles City and Los Angeles County portions. The areas of concentrated hillside residential development were graded primarily from about 1950 to 1958. The quality of this grading has proven to be extremely variable.

*Slope Segments (1A through 1H) ***

For this study, Sub-area 1 has been divided on Plate 1 and Table 3a (in pocket of report) into eight slope segments based on topography and the manner and history of development. Slope segment discussions that follow include manner of development, specific and general comments on slope problems, and general recommendations on the types of repairs and protective measures that might be employed to alleviate the problems. It should be noted here that the particular pattern and density of development and the steep slopes within Sub-area 1 may make comprehensive corrections difficult. Primary mitigation should include drainage and ground moisture control and protective vegetation or slope covering. Fill stabilization may be necessary to correct already distressed areas.

Slope segment 1A. Bedrock, primarily sandstone and siltstone of the Inglewood Formation (Qi), is cut by three north-trending faults that were mapped by Castle (1960a) and which are shown on Plate 1 herein. The segment is dominated by a steep (45°) cut slope that was made to allow commercial development adjacent to Jefferson Boulevard. Minor cut and fill grading above this slope preceded construction of residences along Hetzler Road and Tompkins Way. Most of this grading was done during the 1940s and the early 1950s. Problems that have occurred in the slope behind the commercial development along Jefferson Boulevard, below the residences along Hetzler Road, have included

*By J.A. Treiman

**Each "slope segment," as delineated in Sub-area 1, actually includes several slopes grouped on the basis of grading and problems or problem potential.

*For authorship, see individual sections.

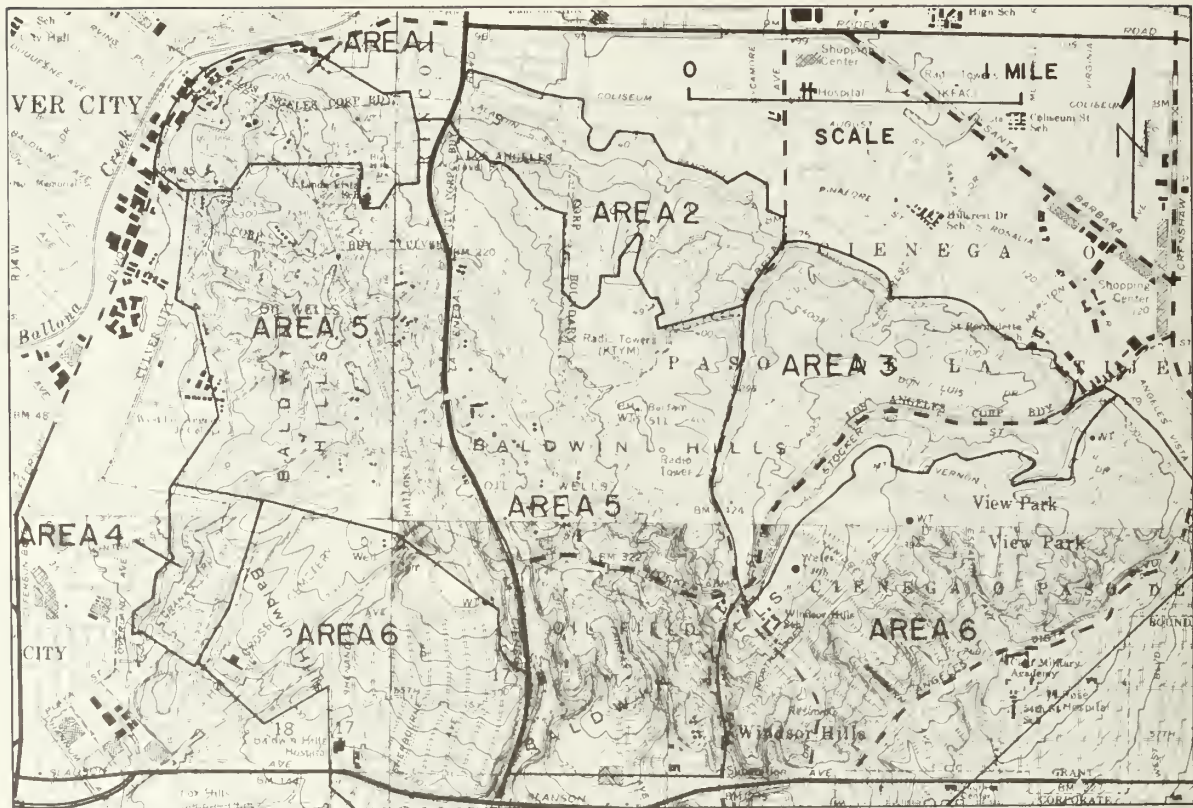


Figure 12. Sub-areas 1-6 were investigated for this study as follows: 1 and 2, by J.A. Treiman; 3 and 4, by E.Y. Hsu and S.S. Tan; 5, by R.B. Saul and F.H. Weber, Jr.; and 6, by Hsu, Tan, and Weber.

deep-seated, bedrock landsliding (Locality 1a, Plate 1, and Photo 14) and surficial slumps up to 6 feet thick. (The houses above this slope on Hetzler Road and Tompkins Way utilize septic waste disposal systems with cesspools or leach fields. Water seepage noted during much of the year at the bottom of the slope behind 6180 Jefferson Boulevard [Locality 1b] may be in part derived from these septic systems.)

Saturation from heavy rainfall (adding to prior ground moisture), coupled with the steepness of the cut slopes, have probably been among the main causes of the slope problems in Slope segment 1A. Inadequate surface drainage within the graded residential area may also have contributed to the saturation of the ground. It may be significant that at Locality 2 (Plate 1) a 70° cut slope, without residential development above it, has experienced only minor sloughing problems. (Localities 1a-b and 2)

Recommended mitigation measures for this area include debris protection (slough walls), drainage control, slope stabilization, and ground moisture control. Part of the ground moisture control effort should be the elimination of leach field seepage by conversion of septic waste disposal to completely closed systems or else by connecting houses to existing sewer systems.

Slope segment 1B. This slope segment, which is within the City of Los Angeles, is essentially undeveloped although some grading occurred on landslide portions of it during the 1950s. The lower portion of the slope segment is underlain by Inglewood Formation (Qi) while the higher parts are underlain by Culver sand (Qc) and Baldwin Hills sandy gravel (Qb) (see Plate 1). Depiction on Plate 1 of two large, pre-development

landslides on this northern slope of Sub-area 1 is based primarily on interpretation of vertical aerial photographs taken in 1927 and 1941 (Photo 3), but the landslides are also visible on oblique photographs taken in 1936 and other years (Photo 2). The larger slide is visible on recent aerial photographs, but the smaller, less well-identified one has been subdued by erosion and grading and is not visible on recent photographs.

Although there has been no indication of historic movement on either landslide, rainfall and surface runoff infiltration should be controlled to inhibit their future reactivation. The slope that includes the smaller of the two landslides has been modified by the creation of several man-made terraces. Drainage here should be controlled to prevent future erosion and ground saturation; non-engineered fill that may be present could be a source of future slumping. Minor road grading on the larger landslide may also need erosion control.

Slope segment 1C. This roughly triangular area of Culver City was largely graded by cut and fill prior to 1953. It is underlain almost wholly by sandstone and siltstone of the Culver sand (Qc). Damage reported here is attributable to fill (af) settlement and creep, which may be indicative of poor control of the original grading in this still sparsely built-up piece of land. Placement of uncontrolled fill was observed by the writer uphill from this graded area during the course of this study. The possibility that much of the fill in this area was not engineered suggests that measures should be taken, at the least, to control surface runoff, erosion, and infiltration of water; the need for more extensive measures should be evaluated in the course of any future development. (Locality 3)



Phata 14. View southwest in 9000 block of Jefferson Boulevard, northwest edge of Baldwin Hills. Landslide shown, which is in a 45° cut slope, occurred initially in 1978 and was partially reactivated early in 1980. The slide mass failed completely in June 1980 during attempts to modify the toe of the slide, damaging the commercial building at the right edge of the phata. (Locality 1, Sub-area 1, Plate 1 and Table 3a). (The damaged commercial building is in the City of Culver City whereas the endangered residential property shown above is in Los Angeles County territory on Hetzler Road.)

Slope segment 1D. Slope segment 1D contains one canyon fill (af, Plate 1) but otherwise was developed by grading parallel to the natural slopes, with long driveways as access to flag lots and with descending fill slopes below several pads. Bedrock is Culver sand (Qc).

Slope stability problems that have been reported in this slope segment have included surficial creep and slumping of fill (af) and soil, as well as deeper slumping or settlement of fill (Localities 4 and 5). Photo 15 shows an example of fill settlement. As in most of the older graded areas, the problems are directly related to oversaturation of steep slopes caused by torrential rainfall and possibly by poor irrigation practice. Remedial measures might include drainage control, ground moisture control, and fill stabilization, as well as debris protection for the lower properties. (Localities 4 and 5)

Slope segment 1E. This slope segment was among the last portions of Sub-area 1 to be developed, having been graded during 1956 to 1958. During this grading, most fill (af) utilized for development of residential lots was placed on the lower portions of the segment; higher lots were cut in Inglewood Formation (Qi) and Culver sand (Qc). The only slope problem known to the author is a single cut-slope failure that occurred in 1978 (Locality 6, Table 3a). This localized problem in a steep cut slope may have been related to weak rock in proximity to a northwest-trending fault, as mapped by Castle (1960a; and depicted on Plate 1 herein). Most future problems here should be preventable through proper control of runoff and moisture infiltration and planting and maintenance of appropriate vegetation.

Debris or slough walls might provide added protection below the cut slopes. (Locality 6)

Slope segment 1F. Although graded at approximately the same time as Slope segment 1D, the style of cut and fill grading here was somewhat more complex. This grading produced descending rows of cut and fill lots superimposed on cut ridges and canyon fills. Bedrock includes Culver sand (Qc) and some siltstone and sandstone of the Inglewood Formation (Qi). A north-northwest-trending fault cuts the segment, as mapped by Castle (1960a) and shown on Plate 1, herein.

Stability problems here (Locality 7) have resulted from oversaturation of poorly indurated sandstone in steep graded slopes. Control of drainage and ground moisture should assist greatly in preventing future problems. (Locality 7)

Slope segment 1G. The grading in this slope segment area, consisting of large cut areas and two canyon fills (af), has been much simpler, although no less extensive, than grading in Slope segments 1C through 1F. The only slope problems here have been surficial failures on a 1:1 cut slope in Culver sand (Qc) in 1978. Temporary protective measures prevented damage in 1980. More permanent drainage control and slope protection measures probably would be useful. (Locality 8)

Slope segment 1H. This southwestern portion of Sub-area 1, which is not developed for urban residential use, contains several fills. A large trash fill (af; in the vicinity of the words "Athletic field" on Plate 1) occupies the site of what was previously a



Photo 15. Property on Wrightcrest Drive, Culver City, northwestern Baldwin Hills. Creep and settlement of fill placed during grading for driveway in the early 1950s have caused tilting of the wall and gate shown. (Sub-area 1, Plate 1.)

man-made excavation. Also, several smaller fills have been placed in conjunction with road grading and grading of pads for placement of water tanks. Additional areas of uncontrolled fill in the northeasternmost part of the segment, not depicted on Plate 1, are the result of grading in nearby areas. The condition of these various artificial fills should be evaluated prior to any further development in their vicinity. Until such development occurs problems can be minimized by maintaining control of surface runoff to avoid ponding, excessive infiltration, or erosion.

Sub-Area 2 - North-central Area* (Los Angeles City 90008) (Slope failure localities 9-51)

Introduction and Summary

Sub-area 2 includes the north flank of the Baldwin Hills between La Cienega Boulevard on the west and La Brea Avenue on the east. The area, developed only with single family residences, was graded as a series of adjacent but unrelated tracts beginning in the 1940s and continuing until 1957, when it attained essentially its present configuration (Photo 11). An overhead power transmission line and underlying property of the Los Angeles Department of Water and Power, which bisects the area from north to south, pre-dates tract development. Early tract grading was concentrated on the lower slopes and, until about 1951, was accomplished much as illustrated herein in Figures 13 and 14 by development of streets extending lengthwise along slopes. Much of the later grading involved more extensive altera-

tion of the terrain, including trimming of ridge tops and filling of canyons and gullies. Evidence gathered by the Los Angeles City Department of Public Works indicates that some fills in at least one tract may have been improperly placed directly on natural soil during tract development (see discussion under Slope segment 2M).

The main causes of slope problems in Sub-Area 2 are steep slopes (1½:1 or steeper), inadequate control of runoff, daylighted soil profiles, and saturation of artificial fill. These problems are worsened by the presence of gophers and other burrowing rodents, an area-wide problem that should be treated on an area-wide basis. Rodent control is mentioned in the slope segment discussions when the problem is also specifically known or indicated in that slope.

Slope Segments (2A through 2V)

Twenty-two slope segments, 2A through 2V, have been outlined in Sub-Area 2 on Plate 1 and are described in Table 3b (in pocket of report) and discussed in the text that follows. The discussion of each slope segment contains a general description of conditions within that segment and an analysis of its problems. Some "slope segments" delineated in Sub-area 2 are actually complexes of slopes containing several slope faces that have a common style of development and similar problems, and that may be best treated as one area for the coordination of corrective efforts.

General suggestions as to the type of remedial action needed are given by key phrases (defined below) following each discussion of a slope segment. Suggestions are geared toward prevention of future problems as well as to correction of existing problems. Further discussion of the individual suggested types

*By J.A. Treiman

of remedial action is included in the succeeding section of this report entitled "General Evaluation of the Problems of Slope Failure." Key phrases used in the discussions are as follows:

Drainage control - control of runoff from pads and slopes.

Slope stabilization - stabilization and protection of surficial materials by proper vegetation (V) and stabilization of both bedrock and surficial materials by slope flattening or by use of engineered structures (E).

Rodent control - control of burrowing rodents and repair of their holes, tunnels and other deleterious effects.

Debris protection - prevention or diversion of debris flows.

Ground moisture control - moisture control by use of sub-drains and other methods; prevention and control of water access.

Gully erosion control - protection from concentrated surface runoff of areas vulnerable to erosion.

Fill stabilization - stabilization of soft artificial fill that is settling (as it consolidates) or is otherwise failing.

Slope segment 2A. The slope segment contains only minor cut and fill for pad grading. No damage was observed or reported.

Recommended Measures: Drainage control, slope stabilization (V).*

Slope segment 2B. Fill (af) lots with houses along Aladdin Street lie above a cut slope and accompanying house pads along Brushton Street and part of Carmona Avenue. Some loose fill was placed on the compacted fill slope during tract grading. Minor fill placement completed the lots along Carmona Avenue. Slope failures have consisted primarily of surficial slippage and creep of soil and uncompacted or weathered fill, with damage to properties both at the top and bottom of slopes. Bedrock in cut slopes appears sound except where it is weathered, in which case it is susceptible to minor sloughing and erosion. Loose or weathered fill presents a potential for deeper failures and settlement if deep saturation of the fill material occurs. Some minor settlement of the fill at the western end of this area has caused differential movement of a sidewalk. (Localities 9 and 10)

Recommended Measures: Drainage control, slope stabilization (V,E), debris protection.

Slope segment 2C. A natural slope lies above an area modified by cut-and-fill tract grading. The bedrock (Qi) in cut slopes is generally sound until it weathers; the weathered zone is subject to sloughing, with erosion on bare slopes. Cut and fill slopes below unmaintained or unpaved bench drains may be especially prone to erosion and sloughing (Photo 16). Thick soil and colluvium (Qco) accumulated on the natural slopes present a severe potential for slumping, especially where they are daylighted in cut slopes (particularly see notes for Localities 13a and 15a). Debris flows may be initiated in the steeper slopes near the ridgeline. Piping and gullying occurring in the thick natural soil and colluvium is probably attributable to rodent activity and erosion along dirt bike trails. Thick soil as well as weathered fill and bedrock may be subject to creep on steep slopes. (Localities 11 - 15)

*See introduction for this subsection for description of key phrases and symbols "V" and "E" used in "Recommended measures."

Recommended Measures: Drainage control, rodent control, slope stabilization (V,E), debris protection, ground moisture control (Localities 13a and 15a).

Slope segment 2D. Minor cuts and fills were made for pad grading adjacent to Los Angeles Department of Water and Power (L.A.D.W.P.) transmission lines.

2D₁: Cut and fill slopes are small. No damage was observed or reported. Potential exists for minor soil slips and erosion between lots and on rear slopes.

Recommended Measures: Drainage control, slope stabilization (V).

2D₂: A high, steep cut slope (up to 17 feet high at greater than 1:1) was created here during tract development. Retaining walls were constructed at the base of some of the higher and steeper slope sections. The only damage known here occurred in the early 1950s and was probably related to high rainfall. The slope portion within the Los Angeles Department of Water and Power property appears adequately protected by existing drainage control devices.

Recommended Measures: Drainage control (maintenance), debris protection, slope stabilization (V).

Slope segment 2E. Thick soil, colluvium (Qco) and weathered bedrock (Qi) in the natural slopes are prone to slumps and debris flows, as shown in Photo 17 and described in Table 3b. Judging from topographic maps, aerial photos, and field observations, this may be one of the most active slump areas in the vicinity. Arcuate scarps at the upslope end of this area are evidence of the progressive slope failures occurring here. Small slumps and debris flows have generally not reached the dwellings below due to the flattening out of the lower portion of the slope; however, the potential for larger surficial failures (including flows) to reach dwellings must be recognized as a serious threat.

A possible reason for the high level of slope activity may be related to the presence of a capping of sand and gravel of the Baldwin Hills sandy gravel (Qb) on the ridge above. This porous rock, underlying the largely undeveloped ridge top, has the ability to rapidly absorb rainwater, which then trickles out into the soil and colluvial deposits down slope. If the sand and gravel were not present, much of the incident rainfall would run off over the surface of the less permeable bedrock (Qi) and its overlying soil. Irregularities in the ridge top (once the site of a missile base) also help trap and absorb rainfall. These irregularities include a closed depression about 100 feet long (encircled with hachures in red on Plate 1), at Locality 17a. (Localities 16 and 17)

Recommended Measures: Slope stabilization (E), drainage control, debris protection, rodent control.

Slope segment 2F. Bedrock (Qi) exposed in natural terrain is weathered, and prone to slumping, as are the overlying soils. A prominent north-northeast-trending gully in this slope segment may have formed along a zone of more easily eroded, fractured bedrock created by pre-development faulting. A north-northeast-trending fault that was mapped in the vicinity of this gully by Castle (1960a) is shown on Plate 1.

Both slumping and high runoff have caused problems here. The slumping at the west end of Weatherford Drive is due to several factors: daylighted soils, a steep (1:1) cut slope, fractured and weathered bedrock, and (as noted earlier by consultants) rodent activity (Locality 18). Slumping in the gully walls south of Weatherford Drive is primarily due to storm runoff creating and maintaining the steepness of the walls. A presently existing catch basin in the gully was unable to accommodate the extremely high runoff of March 1980, and the overflow damaged properties below. (Localities 18-20)



Photo 16. Aerial view to the east-southeast in 1978 across Lo Cienega Boulevard shows landslide in cut that partially blocked traffic flow before slide was cleared. Rock in cut is weakened by crushing and fracturing along Inglewood fault (I), which here separates siltstone and sandstone of Inglewood Formation (Qi) from sand and gravelly sand of Culver sand (Qc). Note the effects of dirt bikes on terrain of center and right of photo, and the two surficial landslides (S). Also note steepness of graded slopes in back of houses on Allodin Street (A) and Glenford Street (G). Observe the unmaintained and clogged bench drains (CD) on slope in back of houses on Allodin Street and along Lo Cienega Boulevard. Slope in back of houses on Glenford Street has no bench drain, even though it was graded after 1952 (see Photo 11). (Localities 9-15, Sub-oreo 2, Table 3b and Locality 90, Sub-oreo 5, Plate 1.) Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.



Phata 17. Aerial view southwest shaws slope failures that occurred in 1978 in natural terrain above Carmana Avenue. Wiggly arrows depict surficial debris slides and flaws and erosion; and dual, slightly raunded arraws denate slumping (Locality 16a). Additional slumping and erosion occurred in 1980. Also shawn are the path of a pre-1978 (about 1956) debris flow (heavy dats), areas of thick calluvium (Localities 15a and 16), and arcuate scarps (Localities 17a-c) that have resulted fram progressive, shallow failures. Nate location of closed depression just ta left of Locality 17a which traps water that seeps into the ground. Circled locality numbers and ather slope failure features are described in Table 3b and depicted in red an Plate 1. See also discussions of Slope Segments D and F, Sub-area 2. Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.

Recommended Measures: Slope stabilization (E), drainage control, gully erosion control, rodent control.

Slope segment 2G. Artificial fill (af) is upslope from natural and cut slopes. Most of the grading occurred during tract development. Very little damage was reported to have been caused by the 1978 and 1980 rains. The most significant damage was at the west end of Stillwater Drive where patio settling and slope creep corresponds to the margin of the fill. This relationship suggests that settling of the fill may be the primary cause of damage. Future settling may be avoided by limiting filtration of water into the fill by controlling runoff of rain water and limiting irrigation. (Locality 21)

Recommended Measures: Drainage control, fill stabilization (?), ground moisture control.

Slope segment 2H. Artificial fill (af) emplaced during tract development lies above mostly natural slopes underlain by Qi and Qco. Some cuts for houses occur on Stillwater Drive, Burnside Avenue, and Ridgely Drive. Most of the damage in this slope segment is due to shallow soil slumps and debris flows derived from the fill slope. Uncontrolled or misdirected runoff has created some erosion problems. Many of the small slumps have occurred at the base of the fill, suggesting that excessive water is entering the fill and seeping out below along the surface separating the fill from the underlying bedrock. Watering above this fill should be strictly limited in the rainy season. Landscape vegetation with lower water requirements should be emphasized. Digging and tunneling by gophers has also been noticed as a problem in this area. (Locality 22)

Recommended Measures: Drainage control, slope stabilization (V), rodent control, ground moisture control.

Slope segment 2I. Pads on Weatherford Drive are cut into the natural slope; pads above on Cloverdale Avenue are on both cut bedrock and fill (af). The intervening slope is natural. Bedrock (almost wholly Qi) here is generally firm and subject to only minor erosion. Thick soil has developed on the natural slopes.

Problems in the lower, 1:1 cut-portion of the slope, along Weatherford Drive, have been due primarily to slumping of daylighted soils and minor sloughing and erosion of weathered bedrock. Although no damage was reported in 1978 and 1980 in the easternmost part of the cut slope, it appears that it may have suffered minor sloughing in the past.

A local area of very thick colluvium and soil (or possibly part of an ancient landslide, Qls [?]), daylighted above 5330 to 5370 Weatherford Drive, suggests a relatively more severe threat of slumping (Locality 23). A less well defined area of thick soil above 5414 and 5422 Weatherford Drive may also be subject to large scale slumping in the future unless mitigative action is taken.

Problems in the upper part of Slope segment 2I are primarily attributable to saturation and settlement of artificial fill, with resultant distress to structures founded on the fill. The main problem (Locality 24) has been associated with the largest and most westerly of three fills in the segment; problems to the east at 4067 Cloverdale Avenue may be associated with settlement of the smaller fill to the east. The slopes have also been affected by rodent burrowing, which has contributed to weakening of the fill and of soils and which has provided access for water. Although recent debris flows from the large fill stopped on the lower slope before reaching houses on Weatherford Drive, larger failures in the future could travel farther (see "Remarks" for Locality 22, Table 3b in pocket). (Localities 23 and 24)

Recommended Measures: Fill stabilization, slope stabilization (V,E), drainage control, ground moisture control, rodent control, debris protection.

Slope segment 2J. The main feature of this slope segment is a cut slope created during tract development in 1957. The cut slope exposes Baldwin Hills sandy gravel (Qb) overlain by soil. A paved drain originally existed at the top of this slope but it is currently largely inoperative, varying from well-maintained sections that provide some protection to a few segments that are essentially destroyed. Much of the damage on this slope is due to erosion and can be blamed on the lack of drainage control. Existing batterboard repairs may require additional drainage control measures if erosion continues. Gophers have also contributed to the slope problems here. The property above to the west is essentially open space, along with a Los Angeles Department of Water and Power transmission line corridor. (Localities 25 and 26)

Recommended Measures: Drainage control, slope stabilization (V,E), rodent control.

Slope segment 2K. Slopes here are essentially man-made, consisting of both cut and fill slopes. Damage has been characterized by minor sloughing and erosion of surface material, which has become weathered since the area was graded in 1957.

Recommended Measures: Drainage control, slope stabilization (V,E).

Slope segment 2L. Problems here are almost entirely related to the effects of rainfall on man-made fill (af). Failure in 1978 of the southwest facing fill slope (south of Cloverdale Avenue) probably resulted from saturation of the fill material. Shallow failures occurred in the south and east-facing fill slopes (at Terraza Drive and Cloverdale Avenue). (Localities 27 and 28)

Recommended Measures: Drainage control, slope stabilization (V), fill stabilization (?), ground moisture control, rodent control (?).

Slope segment 2M. This segment is primarily artificial fill (af) with some natural slopes (almost wholly Qi). Both the natural and artificial slopes have had numerous soil slips and debris flows, with subsequent erosion of underlying bedrock. Misdirected runoff at 4122 Terraza Drive has caused an erosion gully and a debris flow above Cloverdale Avenue. Other failures of fill slopes must be blamed on the intense rainfall coming when the slopes probably already had a high moisture content. The massive soil slips on the natural slope may have resulted partly from erosional undercutting of the slope. Gopher activity, although not observed by the writer, may also have been an important factor in fill and natural slope failures. The failures below Cloverdale Avenue (Locality 31) occurred below an existing bench drain and probably resulted from soil saturation caused by overflow of that drain. The soil material that failed was probably loose fill, which commonly underlies the forward edge of paved drains.

Settlement damage at Locality 29, which may be partly storm-related, may be indicative of a potentially larger problem in this slope segment and several adjacent segments. Data from several test holes at this locality and elsewhere drilled by the City of Los Angeles Department of Public Works, Bureau of Standards indicate that much of the canyon fill underlying Tract 19051 (including parts of Slope segments 2J, 2K, 2M, 2N, and 2-O) may have been placed directly on natural soil. A backhoe trench on Terraza Drive further revealed that, at least at one locality, the fill was placed on a relatively steep natural slope without benefit of benching. As a consequence the canyon fill may be slipping gradually downhill along the buried, sloping soil zone. Delayed effects of very wet winters, excessive landscape watering, or other additions of water could re-initiate or accelerate this movement. (Localities 29-31)

Recommended Measures: Drainage control, slope stabilization (V), gully erosion control, rodent control, fill stabilization (?), ground moisture control (?).

Slope segment 2N. Pads at the base of this slope segment were created by filling the canyon adjacent to the natural slope and cutting back the already steep natural slope. The upper lots are essentially cut pads except for the two southwesternmost lots, which are on fill (af). Erosion on one of these latter fill lots was due to uncontrolled runoff from the vacant pad area. Soils and weathered bedrock (Qi) on the 33° to 35° natural slope between the fill slope at the top and the cut slope at the bottom have repeatedly slumped. Daylighting of soil at the top of the 1:1 (45°) to 1 1/2:1 (33.5°) cut slope may have been a factor in this slumping. Saturation during very wet winters of the canyon fill may have caused some settlement and structural distress. (Locality 32)

Recommended Measures: Drainage control, slope stabilization (V, E), debris protection, fill stabilization, rodent control.

Slope segment 2-O. The lower lots here were graded like those across Cloverdale in Slope segment 2N: lower pads are partially on canyon fill (af) and partially in cuts into the steep natural canyon sides. Five of the upper lots are on cut pads and the remaining six are partially or wholly on fill emplaced at the top of the natural slope. Many of the failures in this slope have involved soil and weathered bedrock daylighted at the top of the 1:1 cut slope. Unless mitigated, such failures are likely to continue. Slope failures below some of the upper lots have been notable for occurring immediately below artificial fill. This indicates an excess of water in fill which is seeping out at the boundary between fill and underlying bedrock. (Photos 18, 35, and 37) (Localities 33-36)

Recommended Measures: Drainage control, slope stabilization (V,E), rodent control, fill stabilization, ground moisture control, debris protection.

Slope segment 2P. Development here was accomplished primarily by cutting pads and streets into the natural slopes, with some fill placement. Problems have been, for the most part, limited to erosion in cut slopes and shallow sloughing and erosion in fill (af) and natural slopes. In at least one instance, in 1978, a mud flow affecting one property originated on another property upslope. The occurrence of one small landslide in the steep (1:1) cut slope above Weatherford Drive may have resulted from a zone of weakness where Castle (1960a) mapped a fault (see Plate 1). This suggests a need to anticipate possible slope stability problems elsewhere along faults. (Also see discussion of Slope segment 2F and Locality 18 within that segment). (Locality 37)

Recommended Measures: Drainage control, slope stabilization (V,E), rodent control, debris protection.

Slope segment 2Q. The only reported damage was minor sloughing and erosion in a fill slope in 1978.

Recommended Measures: Drainage control, slope stabilization (V).

Slope segment 2R. This slope segment is composed of three different types of terrain, each with its own particular problems: at the bottom, cut slopes above (south of) Veronica Street; at the top, fill pads and slopes below (north of) El Mirador Drive; and, in between, a soil covered natural slope.

The least severe problems have been, so far, in the lower area where there has been only shallow slumping of daylighted soil and erosion in some of the weathered cut slopes.

The fill (af) at the top of the slope has been the source of numerous slumps and debris flows, many originating at the base of the fill. This suggests that water saturating the fill has concentrated at its base and seeps out along the surface separating the fill from the underlying natural slope. In a consulting report prepared in 1978 for one of the failure localities, excessive hydrostatic pressure in the fill and lack of an adequate drainage system were recognized as the causes of failure. Rodent activity has probably increased the potential for excess moisture in the fill.

The natural slope has thus far suffered mainly from failures originating in the fill above it. In this regard, soil slips initiated at the base of the fill have swept some of the natural soils down slope. Remnants of old revetment or terrace-type slope repairs on the slope suggest that soil slips have occurred in the past. A potential for future problems lies particularly in the central part of the slope: analysis of pre-development aerial photography suggests that an old landslide (Qls[?]), or a thick accumulation of colluvium here may be daylighted in the cut slope below (Locality 38). (Localities 38-40)

Recommended Measures: Drainage control, ground moisture control, slope stabilization (V, E), rodent control, debris protection.

Slope segment 2S. This slope segment consists of a natural slope with a flat cut at the top for building pads. The only problem reported that has caused property damage was at 4113 Punta Alta Drive (above Locality 42) in 1978, where a small surficial slope failure undermined pool equipment in the rear yard. Bedrock consists of Inglewood Formation (Qi) overlain by Baldwin Hills sandy gravel (Qb).

In 1948, during construction of the Baldwin Hills Reservoir, a landslide occurred in the excavation for the east dam abutment (Locality 42). The landslide was partially removed and stabilized by placement of an abutment fill. A more extensive area of older (pre-historic) landsliding has been tentatively identified by the writer based on mapping by the California Department of Water Resources and interpretation of aerial photographs that span the past 53 years (Locality 41). Several small slumps and surficial slides have occurred in recent years within the northern portion of this area of older landsliding (Locality 41a). The future stability of this slope segment should be evaluated. (Localities 41 and 42)

Recommended Measures: Drainage control, slope stabilization (E), rodent control.

Slope segment 2T. The terrain of this slope segment, which has been altered by both cut and fill, still retains some portions of the natural slope. Bedrock (principally Qi) exposed in cut slopes is relatively firm and has experienced only minor erosion. Most of the slope problems here have involved natural slopes, usually where the soils, which are in excess of 3 feet thick, are daylighted at the top of the 1:1 cut slopes. Fill (af), retaining walls, and decking above these natural slopes have been made vulnerable to future damage as soil failure has progressed upslope. A small erosion gully has formed in one locality in the daylighted soil. (Localities 43 and 44)

Recommended Measures: Slope stabilization (V,E), drainage control, debris protection.

Slope segment 2U. Slopes here are almost entirely cut slopes in bedrock (Qb), and problems have been very few. One local site, however, involving four properties, suffered slope damage in 1969 and in 1980. Bedrock at this particular site was probably more deeply weathered than adjoining sites as, before development, it underlay a pre-existing drainage swale. The initial dam-



Photo 18. View north-northeast across Claverdale Avenue shows steep slopes that failed during the rains of March 4-5, 1978 (slopes were covered with plastic sheets after the damaging rains for protection against possible subsequent rains). Slopes yielded relatively shallow debris slides and flaws, and soil slips from cut and fill slopes. Bedrock is very gently dipping silty sand (Qi, Plate 1). Serious damage also was caused to back edges of properties on Veranica Street above far slope at upper right. (Localities 32-37, Sub-area 2, Table 3b and Plate 1.)

age in 1969 involved a surficial slump in the cut slope. Artificial fill used to repair this damage partially failed in 1980, probably from oversaturation of the fill (af). (Locality 45)

Recommended Measures: Drainage control, slope stabilization (V), debris protection.

Slope segment 2V. All of the residences in this complex of slopes are on lots graded at the tops of slopes. Bedrock is Inglewood Formation (Qi). Damage to properties has consisted of undermining of improvements primarily by upslope encroachment of scarps from slope failures (Photos 19 and 20). These failures have comprised surficial sloughing and erosion of fill (af) and soil, much of which probably resulted from misdirected drainage at the tops of slopes. In the southern part of this segment, particularly in slopes below Mantova Drive, recurrent erosion and small scale slumping has endangered some of the previous attempts at slope repair (Locality 50, for example). Rodent activity has undoubtedly played a part in many of the slope failures: the presence of gophers was noted in a consulting report for construction of a swimming pool at 4022 Punta Alta Drive, and gopher activity is apparent at 5232 El Mirador Drive (Locality 47) (see Photos 42 and 43).

A larger, long-range problem involves the deep (up to 15 feet or more) erosion gullies forming in the undeveloped portions of Slope segment 2V. (See Localities 48 and 51, for example). These gullies are gradually working up-canyon and eventually

may seriously undermine both fill and natural slopes below residences. All the gullies except one (in fill) are trenching thick colluvial deposits. The entrenchment may have originated because of over-grazing by sheep in the 1800s or it may be related to lowered erosional base level due to geologically recent uplift of the Baldwin Hills. The earliest aerial photographs studied (taken in 1927) indicate that, prior to any significant grading, erosion was well under way in the canyon now occupied by La Brea Avenue and was beginning to extend up the side canyons (see Photo 4). The erosion did not extend beyond the relatively abrupt base of the hills. A key element in stabilizing the gullies will be establishment of higher base level before backfilling them. This could be accomplished by construction of small check or debris dams at the mouths of the gullies.

Possible factors involving erosion problems in both natural and artificial slopes consist of misdirected yard drainage and the improper use of swimming pool drainage lines. Several hoses and drain lines were observed in 1980 that had directed water onto these slopes, some emptying directly into gullies. It was not possible to determine whether the gullies pre-dated or were caused by the drain lines. Likewise, broken drain lines observed at some localities may have been either the cause of, or caused by, erosion and slumping. (Localities 46-51)

Recommended Measures: Drainage control, gully erosion control, rodent control, slope stabilization (V), debris protection.



Photo 19. Closeup aerial view northwest in 1978 shows intersection of Punto Alto Drive (PA) and Montova Drive (M) and damage to steep slope bordering houses on Montova Drive caused by shallow debris slides and flows, and minor erosion. View shows that small building in back of swimming pool on property at left-center of photograph has been slightly undermined by the sliding. Note edge of concrete retaining structure at left edge of photo that protects property mostly out of view. Contact shows part of the boundary between gently dipping Inglewood Formation (Qi) and overlying artificial fill (af) employed during grading for tract. Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.



Photo 20. Closeup aerial view to the northwest in 1978 shows slope damaged by debris flows and erosion just south of intersection of Punto Alto Drive (PA) and Montovo Drive (M) (Locality 50, Sub-area 2, Plate 1 and Table 3b). (Site of Baldwin Hills Reservoir lies to left of the photo scene.) Note contributing and possibly contributing factors to slope failure: A, fence and anchoring device that collapsed; and B, remnants of lush vegetation that suggests overwatering or seepage of water into slope, possibly from swimming pool leakage. Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.

Sub-Area 3 - Northeastern Area*
(Los Angeles City 90008 and the north edge of
View Park - Windsor Hills,
Los Angeles County, 90043)
(Slope failure localities 52-81)

Introduction

Sub-area 3 is located in the northeastern part of the Baldwin Hills and is triangular in shape. It is bounded by La Brea Avenue on the west, Stocker Street on the east and southeast, and the eastern part of the steep north-facing escarpment of the hills on the north. The sub-area is wholly within the City of Los Angeles except for the southernmost part, which consists of a slope along the south side of Stocker Street. This slope is at the north edge of the community of View Park - Windsor Hills of the County of Los Angeles.

Development of the northeast part of the Baldwin Hills began in 1927 on the lower slopes of what became View Park - Windsor Hills. The athlete's village for the 1932 Olympic games was constructed in this area. La Brea Avenue and Stocker Street were put through the hills in about 1936 and 1941, respectively. Development of the Los Angeles City portion of Sub-area 3 began in about 1950 in the eastern part of the sub-area and extended westward mostly as a continuing series of adjoining tracts consisting primarily of single family residences. Apartment buildings were constructed along Don Ricardo Drive at the northern edge of the area, along Don Tomaso Drive at the southern edge of the area, and along a few additional streets. Development was mostly completed by 1959. Construction of a condominium complex was underway in early 1981 just south of Don Lorenzo Drive.

Development of the steep-sloped terrain of this area was carried out using cut and fill to grade canyons and ridges for placement of building pads. Grading was done mainly by following the natural configuration of the terrain. For example, Stocker Street, Don Miguel Drive, Marlton Avenue, and Hillcrest Drive were constructed along the bottoms of pre-existing canyons. Commonly, the steep natural slopes along the sides of the canyon bottoms were cut back so that a row of pads could be developed along each side of the street in a canyon. Additionally, crests of ridges were cut downward, and the cut material placed along the edges as fill to make the ridges wide enough for a street and a row of pads for houses along each side of the street (Photo 12). Streets developed along ridges included Don Mariano Drive and Don Ibarra Place. This method of development caused already steep natural slopes to be made even steeper. Both the fill slopes along the tops of ridges and the cut slopes along the bottoms of canyons in Sub-area 3 have been damaged by torrential rains in 1969, 1978, and 1980. Typical hillside conditions are illustrated in Figures 13 and 14.

Slope Segments (3A through 3X)

Detailed descriptions of slope failures and accompanying damage for Localities 52 to 81 in Sub-area 3 that are shown on Plate 1 are presented in Table 3c (in pocket of report). Sub-area 3 is divided into 23 slope segments (3A-3X), as outlined on Plate 1, for description and evaluation of past slope failures and potential hazards. Such failures and potential hazards may extend over several or more properties on a single slope, in which case the slope can be stabilized only by a joint effort among the owners of all properties affected. General recommendations for

the stabilization of slopes are made in a succeeding section of the report.

Slope segment 3A. This segment consists of a generally uniform, composite slope that stretches for nearly 1 mile along the east side of La Brea Avenue, with single family residences bordering the top of the slope for its entire length. The northern and central portions of the slope have a height of 100 to 150 feet, which diminishes southerly from the central portion to 30 feet at the south end. Most of the northern and central portions consist of natural terrain, with a slope gradient of 2:1, underlain by siltstone of the Inglewood Formation (Qi). The south portion consists mostly of fill (af) slopes with gradients of 1½:1 or steeper. The natural slope is overgrown with grass and shrubs and contains a few trees. Paved bench drains are present only on the fill slope at the south end of the segment. Some fill portions of the slope along the top of its central and northern parts have a slope gradient of 1½:1 or steeper.

About 19 of the 57 residential properties at the top of the slope are reported to have had problems related to slope failure. Most of these failures occurred in 1978 when at least six residences sustained structural damage. Most of the properties damaged are at the top of fill slopes in the south part of the segment, along Don Miguel Drive. Most of the failures originated either at the top of the slope or just below a bench drain on the slope, which is indicative of one or more of three possible problems: (1) improper ponding of water in backyards; (2) discharge of water over the backs of yards and down slopes; and (3) obstruction of bench drains due to growth of ice plant and accumulation of debris (see Localities 52 - 54, Plate 1 and Table 3c).

A failure originating in a fill slope at 4659 Don Miguel Drive consisted of a debris flow 50 feet wide that extended down a natural slope (north end of Locality 53). Also, the property at 4785 Don Miguel Drive (part of Locality 54) was damaged in 1978. It was reportedly damaged also in 1967 and 1973 and repaired in each of those years with engineered (soil-cement) fill. Apparently, however, the presence of the soil-cement fill did not prevent the slope from failing again. (Localities 52 - 54)

Slope segment 3B. This short, north-facing segment is almost entirely underlain by siltstone of the Inglewood Formation (Qi). The entire slope is about 50 to 75 feet in height with a 1½:1 slope gradient at the base along Don Ricardo Drive, steepening up-slope to a 1:1 gradient along the base of properties on the north side of San Jose Drive. A wide, unpaved bench in the middle of the slope drains west toward La Brea Avenue.

The cut slope below the bench has been subjected to various degrees of erosion, with some of the erosion gullies developed having originated at the top of slope. The erosion gullies have a maximum depth of about 4 feet. Also, the cut slope above the bench has been subjected to soil slips and shallow slumps (Localities 55 and 56) that have had a maximum depth of 3 to 5 feet. Some of the slope damage in 1978 was repaired with a revetment system that was undermined by the 1980 rains. No structural damage has been reported. (Localities 55 and 56)

Slope segment 3C. This slope segment, which is located between Don Rudolfo Place and Don Jose Drive, consists of a non-uniform slope with a gradient ranging from 45° to 70° and a height ranging from 25 to 65 feet. The gradient lessens gradually to the south, with an angle of 45° (1:1) at the east end. The bedrock consists of siltstone of the Inglewood Formation (Qi). A wedge of artificial fill (af) is located in the western portion of the slope. There is no bench drain on the slope. The slope is planted with ivy, ice plant, and shrubs.

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Slope damage in 1978 was caused mainly by soil slips and surficial erosion with a reported maximum depth of 3 feet. Most of the failures occurred in portions of the segment steeper than 1½:1; gently sloping portions apparently have not been subject to failure. At least five properties were damaged in 1978. One house suffered structural damage due to slope failure at the top of the slope (Locality 57). One property was also reported to have been damaged in 1969. (Locality 57)

Slope segment 3D. This slope segment is divided into three subsegments:

3D₁ - The subsegment is located between Don Arturo Place and Don Pablo Place. It consists of a uniform slope with a gradient ranging from 1:1 to 1½:1 and a height of 25 feet. The slope is underlain by sand and gravel of the Baldwin Hills sandy gravel (Qb) and by fill (af). Available data and study of 1980 aerial photographs indicate that two properties on the fill portion of the slope were subjected to slope damage caused by erosion and soil slips in 1978 and 1980.

3D₂ - This subsegment consists of a steep (1:1) central cut slope with gentler (1½:1) swale-like features on either side; northwest

of the more westerly swale the segment is uniform. The height of the slope is generally about 50 feet and it is mostly planted with ivy. It is partly underlain by fill (af) placed in a pre-development canyon and partly by siltstone of the Inglewood Formation (Qi). The slope is provided with a bench drain that discharges runoff onto Don Rudolfo Place. East of the cut, the slope is characterized by a large semi-circular swale that has a 1½:1 gradient. Most properties on the slope are planted with ivy. (Localities 58 and 59)

At least 14 properties have been affected by slope failure in 1969, 1978, and 1980, but none have suffered structural damage. Most of the failures occurred in 1978. Most have occurred in the fill portion of the slope as soil slips, debris flows, and erosional gullies that originated at the top of slope (Photo 21). The retaining wall of one property was reported to have been distressed due to failure of the slope (see Localities 58 and 59). The cut slope itself has also been subjected to failures below bench drains.

3D₃ - Included in this subsegment at its extreme east end is a large 1:1 cut slope along Don Ricardo Drive. This slope, which is 75 to 135 feet high, occurs below a gentler natural slope. Between the cut slope and the natural slope is an unpaved bench.



Photo 21. Closeup aerial view south in 1978 shows five distinct, very shallow debris flows that caused damage to slope between Don Alegre Place (DA) and Don Milagro Drive (DM) at top and two properties on Don Rudolfo Place (DR) at the bottom. Slight undermining of patios and walls occurred at the top of the slope and damage to a fence and other backyard improvements occurred at the base. Damage was small because volume of debris was small; it consisted only of a veneer of vegetation and weakly developed soil overlying weathered fill and bedrock. (Localities 58 and 59, Sub-figure 3, Plate 1 and Table 3c.) Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.

The cut slope below the bench has been subject to extensive erosional rilling and soil slips with a maximum depth of 5 feet. The natural slope above the cut had not been damaged. A slope failure below 4500 Don Rudolfo Place has been repaired with a gunite cover and a revetment system. The effectiveness of such repairs during future heavy rains remains to be evaluated.

Slope segment 3E. This segment is divided into three subsegments:

3E₁ - This subsegment is located between Don Carlos Drive and San Jose Drive. It consists of a slope with a 1:1 gradient that is 15 to 25 feet high. It is underlain mainly by the Baldwin Hills sandy gravel (Qb), with artificial fill (af) at the top. Only minor erosional problems have been reported. Erosion has occurred on slopes covered with ice plant and ivy.

3E₂ and 3E₃ - These subsegments apparently have slopes insufficiently large and steep enough to have suffered damaging slope failures.

Slope segment 3F. This segment consists of a relatively uniform slope, except behind 4466 to 4480 Don Milagro Drive, where a steep bedrock protrusion extends toward the street. The lower, natural and cut portions of the slope are underlain mostly by siltstone of the Inglewood Formation (Qi) and partly by Baldwin Hills sandy gravel (Qb). Artificial fills (af) were placed discontinuously along the top of the slope. Where uniform, the slope is 20 to 60 feet high and has a gradient of 1 1/2:1 to 1:1. A wide bench, which is located above the steep bedrock portion of the slope, behind 4472 Don Milagro Drive, inclines downward easterly with a 2:1 gradient toward 4466 Don Milagro Drive. The slope is planted mostly with ivy.

Damaging slope failures occurred mainly in 1978 as soil slips and surficial erosion. The maximum depth of failure was about 3 feet. About 11 properties were reported to have suffered slope damage but no houses were subjected to structural damage. The most serious slope failure occurred at 4472 Don Milagro Drive (see Locality 60). Some of the failures were repaired with revetment systems, most of which do not seem to be adequate to protect slopes during future heavy rains. Low slough walls were constructed on one property to divert or stop potential mud flows. (Locality 60)

Slope segment 3G. This segment, which is located between Hillcrest Drive and Don Alegre Place, consists of a non-uniform slope that is 75 to 100 feet high. The original 2:1 natural slope is present mostly only along the mid-part of the segment; the lower part was cut back during grading for placement of pads, and a fill (af) was placed along most of the upper part of the slope. The fill slope has a gradient of 1 1/2:1 to 1:1. Bedrock underlying both natural and cut slopes consists of siltstone of the Inglewood Formation (Qi). Both the cut and fill slopes are mostly covered with ice plant.

Seven properties were reported to have been affected by slope failure in 1978 and 1980. These failures consisted mainly of erosion in the cut and fill portions of the slope; failures are not known to have originated in the natural portion. The most serious failure occurred in 1980. It consisted of a debris flow that originated in fill in the backyard of 4224 Don Alegre Place, rushed easterly down-slope along a natural gully, and struck two houses at the base of the slope on Hillcrest Drive. The house (4217) that took the greatest impact was eventually demolished (Photo 22). (Locality 61)

Slope segment 3H. This segment consists mainly of a nearly uniform 1 1/2:1 slope that extends along the south side of parts of Hillcrest Drive, Don Diablo Drive, and Don Arellanes Drive.

The uniformity is broken only by a swale at the center of the segment between Don Felipe Drive at the top and Don Diablo at the bottom. The swale has a slope gradient of 2:1. The main slope ranges in height from 30 to over 100 feet. The eastern portion is mainly planted with grass and the western portion with ivy; trees are locally abundant, particularly in the swale. The slope is underlain by siltstone of the Inglewood Formation (Qi) except along Don Ortega Place, where it is underlain by the Baldwin Hills sandy gravel (Qb). An artificial fill (af) has been placed along the top of the slope east of Don Ortega Place and between Don Hillcrest Drive and Don Milagro Drive.

Slope damage occurred mainly in the western portion of the segment. This damage was caused by shallow erosional gullies and soil slips originating in fill slopes. The depth of these failures was probably not more than 3 feet. Eight properties are reported to have been damaged in 1969 or 1978, but only one house has been structurally damaged.

A steep (1:1 to 1 1/2:1) slope between Don Ortega Place and Don Felipe Drive is 35 to 60 feet high. Three properties were reported to have been damaged in 1969 and 1978 along this slope, with one house suffering structural damage. (Locality 62)

Slope segment 3I. This lengthy segment is located mainly along the north side of Don Diablo Drive and partly between Don Diablo Drive and Hillcrest Drive. It consists of a generally uniform slope with a 1 1/2:1 to 1:1 slope gradient and a slope height of 50 to 60 feet. There is no bench drain on it. The only houses at the base of slope are along the east side of Hillcrest Drive. The base and middle of the slope are underlain by siltstone of the Inglewood Formation (Qi); artificial fill (af) was placed along the top of the slope during development in the 1950s. The slope is planted almost entirely with ivy.

Approximately 17 properties have suffered slope damage in 1978, 1980, and other years. Three of these properties also have had structural damage. Damage has been caused by soil slips, surficial erosion, and erosional gullies with a maximum depth of 5 feet. The average depth of most of the failures was probably in the order of 2 to 3 feet (see Localities 64 - 66). Most of the failures are in the upper parts of the slope in fill. Many of these failures were considered by a Los Angeles City inspector to be the result of poor yard drainage. The 1 1/2:1 slope just south of the apartment building at 4106 Hillcrest Drive was subjected in 1980 to a shallow slump failure that had a 2-foot scarp. The failure occurred in clayey colluvium.

Study of pre-development aerial photographs indicates that there probably are two large, pre-development ancient landslides in the western portion of the segment. There apparently has not been any movement involving these landslides, however, since the development in the early 1950s. (Localities 64 and 65)

Slope segment 3J. This slope segment is divided into three subsegments:

3J₁ - This subsegment, along the south side of Don Diablo Drive, is generally uniform and steep, with a 1 1/2:1 to 1:1 gradient. The slope is 50 to 70 feet high between Don Alanis Place and Don Diablo Drive, and 50 to 120 feet high between Don Ibarra Place and Don Diablo Drive. Artificial fills (af) underlie the upper part of the slope, along with a bench drain, north of Don Alanis Place and Don Diablo Drive. The entire slope is planted with ivy.

Slope failures causing damage to 22 properties, 3 with structural damage to houses, occurred mainly in the fill portion of the slope. Most of these failures originated at the top of the slope or just below the bench drain midway on the slope. The failures included erosional rilling, debris flows, and minor soil slips.



Phata 22. View west shows path of debris flow that originated in fill that was placed during development for backyard of residence on Don Alegre Place shown at top of slope. The an-rushing watery debris of the flaw seriously damaged the house to the left and caused lesser damage to the house on the right at the battam of the slope on the west side of Hillcrest Drive. The flaw occurred an February 16, 1980; the phata was taken in April 1980. By February 1981, the seriously damaged house had been razed and a new house was being constructured. (Locality 61, Sub-area 3, Plate 1 and Table 3c.)

3J₂ - This subsegment, between Don Ibarra Place and Don Alanis Place, is characterized by a 1 ½:1 to 2:1 semi-circular slope that is 70 to 85 feet high. The slope apparently has not been seriously damaged by slope failure. However, runoff from this slope carries debris and muddy water to the street during the rainy season, indicating a possible potential for future serious damage. Study of pre-development aerial photos indicated that this area is probably part of an ancient massive landslide, although there has not been any known renewed movement since development in the 1950s.

3J₃ - This relatively non-uniform slope subsegment, between Don Ibarra Place and Don Felipe Drive, has a height of 50 feet and a gradient of 1:1 to 1 ½:1. The upper part of the slope beneath Don Ibarra Place is underlain by sand and gravel (Qb) and the lower portion of the slope is underlain by siltstone (Qi). Two smaller areas of damage in 1978, including Locality 67, resulted from soil slips and shallow slumps; a larger area of damage resulted from soil slips, shallow slumps, and erosion. These failures originated at the top of slope (which was planted with large-leaf ice plant). Some of the failures have been repaired with revetment systems that do not appear to be adequate for long-term stabilization. In addition, the house at 4115 Don Ibarra Place was reported to have cracked, probably due to settlement of artificial fill (af) beneath it. Such settlement generally indicates that a fill was not properly compacted during development. (Locality 67)

Slope segment 3K. This segment is located mainly between Don Felipe Drive and Don Mariano Drive. The principal part of the segment consists of a 1 ½:1 to 2:1 natural slope with a maximum height in its center of about 85 feet, tapering gradually

toward both the east and west ends. During development, the base of the slope was cut back with steep angles (45° to 70°) to accommodate the building lots. The slopes are underlain by sand and gravel (Qb), and are planted mainly with ivy and locally with ice plant and grass.

Eight properties were reportedly subjected to slope damage in 1978. This damage was caused by shallow slumps, soil slips, and debris flows (see Localities 68 and 69 and Photo 23). Most of these slope failures originated at the tops of slopes and had a maximum depth of 3 feet. Surficial erosional problems are also common.

A small portion of this segment consists of a 1:1 slope 25 - 30 feet high located between Don Tapia Place and Don Luis Drive. This portion of the slope does not appear to have been damaged. (Localities 68 and 69)

Slope segment 3L. This segment is located between Don Mariano Drive and Don Luis Drive. It consists of a 1 ½:1 to 1:1 slope that is 10 to 25 feet high. The natural slope before development was entirely underlain by Baldwin Hills sandy gravel (Qb). During development in the 1950s, artificial fill (af) was placed in some pre-existing gullies and on top of slopes. The slope is planted with ivy.

No slope failures were reported in 1978 and 1980. The relatively few slope failures reported to have occurred in 1969 consisted of shallow soil slips in both fill and cut slopes. Settlement and wedge-failure (Figure 14) of fill reported to have occurred in 1968 resulted in damage to the rear side of the house at 4260 Don Mariano Drive (see Locality 70). This settlement indicates that the fill apparently was not properly compacted during development. (Locality 70)



Phata 23. View south shows shallow slump and erosion which occurred during the rains of 1978, damaging backyard of house shown located on the north side of Dan Mariana Drive. Failure originated in fill. Note the repaired slope and the newly constructed retaining wall at the left edge of the photo. Photo was taken in April 1980. (Locality 68, Sub-area 3, Plate 1 and Table 3c.)

Slope segment 3M. This segment is divided into two subsegments:

3M₁ - This subsegment is situated between Don Luis Drive at the top and Don Felipe Drive at the bottom. The subsegment consists of a relatively uniform slope with a maximum height of 90 feet or more that diminishes gradually in height to the west. The lower part of the slope is mostly underlain by siltstone of the Inglewood Formation (Qi) and the upper part mainly by the Baldwin hills sandy gravel (Qb) and fill (af). The bedrock portion the slope has a 2:1 gradient; the fill portion has a 1:1 gradient. The fill portion is planted with ivy.

Several soil slips and erosional rilling occurred in the fill portion of the slope in 1978. A large soil slip that yielded a debris flow originated in fill at the top of the slope at 4046 Don Luis Drive and resulted in extensive damage to the backyard patio of this property. The failure probably resulted from improper backyard drainage, which allowed water to flow over the slope. Additional slope damage resulted from erosion or minor soil slips in steep cut portions of the slope. The maximum depth of failure was 3 feet.

3M₂ - This easterly trending subsegment between Don Tomaso Drive and Don Luis Drive consists of an irregular, non-conforming cut and fill slope ranging in height from 35 to 50 feet. The upper part of the slope generally has an angle of about 30-35° (1½:1); the lower part, where the natural terrain was cut back steeply at the base to make room for pads for apartment buildings and houses, has an angle of 45° - 70° (1:1 and steeper). Swales within this segment are mostly pre-existing gullies that were partly filled during grading for tract development during the early 1950s. The upper part of the slope is underlain by sand and gravel (Qb) and the lower part by siltstone (Qi).

Only a few small soil slips and erosional features were reported or observed to have occurred in 1978 and 1980. These failures occurred mainly in steep, ice plant-covered cut slopes. The available information indicates that the depth of the failures was less than 3 feet.

Slope segment 3N. This segment is divided into three subsegments:

3N₁ - The western subsegment is located between the west ends of Don Felipe Drive and Don Miguel Drive. It consists of a uniform 1:1 slope with a maximum height of 60 feet which tapers downward gradually to the west. Almost the entire slope is planted with large leaf ice plant. Artificial fill (af) is located along a part of the top of the slope along Don Felipe Drive. Bedrock is Inglewood Formation (Qi) and Baldwin Hills sandy gravel (Qb). Most of the reported or observed slope failures consisted of shallow soil slips and erosional features that occurred in the fill (Locality 71). The maximum depth of failure was reported to be 3 feet. (Locality 71)

3N₂ - The central subsegment is located along the north side of Don Miguel Drive, just northwest of its intersection with Don Tomaso Drive. The sub-segment consists of a non-conforming slope 50 to 70 feet high with two large intermediate swales. The gradient of the slope mostly is steep (1:1 to 1½:1) except for the two swales, which are much more gentle (2:1 to 3½:1). Bedrock is Inglewood Formation (Qi) and Baldwin Hills sandy gravel (Qb). Damage reported and observed at the top of the slope was caused mainly by soil slips and erosion in fill (af) (Locality 72). The maximum depth of these failures was about 3 feet. Concentrated runoff down the two swales during heavy rains has caused debris-flow damage to houses at the base of the slope. Flow down the westerly swale drains laterally to the south along the slope; in 1978 this flow apparently damaged the third house northwest of Don Tomaso Drive on Don Miguel Drive. Slough walls with sufficient free-board should be constructed in order to alleviate the potential hazard from further debris flows down these swales. (Localities 72 and 73)

3N₃ - The eastern subsegment is located east of the intersection of Don Miguel Drive and Don Tomaso Drive (Photos 24 and 25). It consists of a more or less uniform, non-conforming 1 ½:1 slope with a steep (45° to 70°) cut at the base (Photo 23). The slope height ranges from 35 to 75 feet. The lower part of the slope



Photo 24. Aerial view to the northwest across Stocker Street (S) in 1978 shows slopes bored by surficial debris slides and flows and by erosion during the rains of March 4-5, 1978. Apartment buildings damaged at base of slope are on Don Tomoso Drive (DT), and single family residences of top of slope are on Don Luis Drive (DL). Street at left of photograph is Don Miguel Drive (DM). (Localities 73 and 74, Sub-area 3, Plate 1 and Table 3c.) (Arrow in right background marks path of debris flow on northwest side of Hillcrest Drive in 1980 [Locality 61; Photo 22].) Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.



Photo 25. Closeup aerial view to the northwest shows the effects of the 1978 rains on the steep slope north of the intersection of Don Miguel Drive (DM) and Don Tomoso Drive (DT). Shallow debris slides and flows, and erosion caused damage to apartment buildings at base of slope on Don Tomoso Drive (Photo 26) and endangered backyards of single family residences on Don Coto Place (DC). (Localities 72 and 73, Sub-area 3, Plate 1 and Table 3c.) Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.

is underlain by siltstone of the Inglewood Formation (Qi) and the upper part by Baldwin Hills sandy gravel (Qb) and artificial fill (af). (Locality 74)

Summary - About 38 properties in Slope subsegments 3N₁₋₃, are reported to have suffered storm-related slope damage; structural damage to buildings has occurred on eight of the properties. The damaging failures have consisted of shallow slumps, soil slips, surficial erosion rills, and erosional gullies with a reported maximum depth of 3 feet (Localities 73 and 74). Some fills and retaining walls at the top of fills and retaining walls at the top of the slope also gave way, and erosion bared the slope to bedrock at some localities. This slope was one of the most extensively damaged in the Baldwin Hills in 1978. The watery debris from the failures piled up in narrow confines at the backs of the apartment buildings and their accompanying carports and garages (Photo 26). The material oozed or crashed into some apartments, shattering plate glass sliding doors and even breaking walls of some flimsy structures. It took many weeks to clean up the mess and repair the damage to buildings. In 1980, the effects were much less severe because so much of the existing surficial material on the steepest parts of the slope had come down in 1978 and only erosion cutting into the bared bedrock slope was a

significant problem. By mid-1980, some new retaining walls had been constructed at the top of the slope and less to more sophisticated revetment systems had been constructed on individual properties (Photo 39). However, some of these revetment systems do not appear to be adequate and may be subject to deterioration in future storms.

Slope segment 3-0. This segment is divided into three subsegments:

3-0₁ - This subsegment is located between Don Zarembo Drive and Don Miguel Drive. The slope has a maximum height of 65 feet and tapers gradually towards the west end. The eastern portion of the slope has a gradient of 1½:1 to 2:1 with a 1:1 cut at the base; the western portion has a 1:1 gradient. The eastern half of the slope is underlain by siltstone (Qi) and the western half by sand and gravel (Qb). The slope is mostly planted with ice plant.

Only two slope failures, which occurred in 1978, have been reported. The exact nature of these failures is unknown, but they may have consisted of erosional rills and shallow soil slips. One of the failures resulted in the failure of a retaining wall at 4470 Don Miguel Drive. (Locality 76)



Phata 26. View east behind apartment building on Dan Tamasa Drive shown in Phata 25. Men shown are cleaning debris from slides and flaws that piled up behind, then entered the apartment building to the right during the rains of March 4-5, 1978. The debris was derived from surficial alluvium and soil developed on bedrock underlying the steep (45°) slope. The bedrock consists of gently dipping beds of silty sand and siltstone which are part of the Inglewood Formation (Qi, Plate 1).

3-0₂ - This subsegment is located between Don Valdes Drive, Don Quixote Drive, and Don Tomaso Drive. The subsegment is underlain mostly by siltstone of the Inglewood Formation (Qi), with artificial fill (af) in the upper portion along Don Valdes Drive. The subsegment consists mainly of non-conforming slopes 45 to 65 feet high. The gradient of the upper, fill portion of the slope is generally 1 ½:l to 2:l, and the lower, cut slope has a gradient of 1:l or steeper. Most of the slope is planted with ice plant. (Localities 75 and 76)

Summary - About 20 properties have been damaged by slope failure in 1969, 1978, and 1980 in Slope subsegments 3-0₁₋₂. These include an apartment building that was damaged by a debris flow. The failures have consisted of soil slips, shallow slumps, and erosional gullies that mostly originated in fill or natural portions of the top of the slope (see Localities 75 and 76). Slumps and erosion also have occurred in steep cut portions below the base of the fill. The failures have had a maximum depth of 5 feet, with most 1 to 3 feet in depth.

Some of the slope failures have been repaired with combinations of engineered fill and revetment systems. The revetment systems, however, do not appear to be wholly adequate and may be subject to failure in the future. One portion of the slope (4506 Don Valdes Drive) is known to be repaired with engineered fill mixed with 20% portland cement.

Slope segments 3P, 3Q, and 3R. Slope segments P, Q, and R share the same slope characteristics; they consist of uniform, moderately low slopes (about 20 to 30 feet high) with a gradient ranging from 1 ½:l to 1:l. Most of the segments are planted with ivy and locally with ice plant.

Slope failures have consisted mostly of shallow erosional rills and a few minor soil slips. Two properties in Slope segment R are reported to have been damaged: one in 1978 and one in 1980.

Slope segment 3U. This segment includes three subsegments:

3U₁ - Along Don Quixote Drive, the subsegment consists of a slope approximately 25 feet high with a gradient ranging from 1 ½:l to 2:l. There are steep cuts and retaining walls at the base of the slope at the southeast end. The southeastern portion of the slope is underlain by siltstone of the Inglewood Formation (Qi) and the northwestern portion is underlain by Baldwin Hills sandy gravel (Qb) and artificial fill (af). Most of the slope is planted with ivy. Slope failure consists of surficial erosion at a few localities.

3U₂ - This subsegment, which is located between Don Tomaso Drive and the east end of Don Lorenzo Drive, consists of a 1:l to 1 ½:l slope that is approximately 40 feet high. The base consists of a steep (45° to 70°) cut with a low retaining wall (mostly less than 6 feet high). The slope is underlain by siltstone of the

Inglewood Formation (Qi) along Don Tomaso Drive and by artificial fill (af) between Don Lorenzo Drive and Don Porfirio Place. The slope is planted with large-leaf ice plant.

The most significant slope failure has been a slump that occurred in 1980 at the top of the backyard behind 4701 Don Porfirio Place and involved three properties downslope to the east along Don Tomaso Drive. The failures have a maximum depth of 5 feet, with a scarp 7 feet high (see Locality 77). Additional damage has been caused by erosion and minor soil slips in ice-plant covered slopes (Photo 27).

3U₃ - The third subsegment is located between Don Porfirio Place and Don Zarembo Drive. It consists of a 1:1 slope approximately 30 feet high. The subsegment is underlain by the Baldwin Hills sandy gravel (Qb) and minor fill (af), and is planted with both ice plant and ivy.

Shallow erosion has occurred on slopes planted with ice plant and ivy. A vacant lot adjoining the intersection of Don Zarembo Drive and Don Lorenzo Drive has been subject to extensive erosional damage due to its lack of vegetation cover.

Slope segment 3V. This lengthy segment, which is in County of Los Angeles jurisdiction, is located along Stocker Street west of Valley Ridge Drive. The slope ranges in height from about 75 to 125 feet. The lower and middle parts of the segment consist mostly of a natural slope with a 2:1 to 3:1 or flatter gradient; a steep (1:1 to 1 1/2:1) fill slope is located along the top of the segment. The natural portion of the slope is overgrown with grass and shrubs, whereas properties along the top of the fill slope are planted with ice plant and ivy. Bedrock consists mainly of sand and gravel of the Baldwin Hills sandy gravel (Qb). The lower portion of the north part of the slope consists of siltstone of the Inglewood Formation (Qi). No construction of buildings has taken place along the base of the slope.

The most prominent slope failures have consisted of shallow slumps, soil slips, and erosional gullies. The majority of these failures have occurred in the artificial fill (af) at the top of the slope or just beneath the base of the fill. Concentrated run-off in natural swales below the fills has also caused extensive erosional gullies (see Localities 78 - 80). Many of these gullies are as deep as 10 to 15 feet. Some of the failures are located at the top of natural drainages or swales, suggesting that water seeping down through the fill during rainy seasons may have flowed out along the base, perhaps undermining the fill in the process. Seepage has been observed at the base of this fill where thick growths of large bladed grass occur.

Only properties listed by Los Angeles County as damaged are depicted (with round black symbols) as damaged in this segment on Plate 1 of this report. The slope portions of some properties on Mount Vernon Drive and Enoro Drive in the vicinity of slope failures mapped (in red) also appear to have been damaged, depending on the downslope boundaries of the property. (Localities 78 - 80)

Slope segment 3W. This segment is located along Stocker Street between Valley Ridge Drive and Presidio Drive. It consists of a natural slope, with a 2:1 to 1 1/2:1 gradient, that is 100 to 120 feet high. Artificial fill (af) with a 1:1 slope gradient was placed at the top of the slope along Kenway Avenue during development. The bedrock consists of siltstone of the Inglewood Formation (Qi) in the lower portion of the slope, and sand and gravel of the Baldwin Hills sandy gravel (Qb) in the intermediate portion of the slope.

Damaging slope failures have consisted of shallow to moderate depth slumps, soil slips, and erosional gullies. The most significant failure, a slump, yielded a 7-foot high scarp and had a probable depth of 4 feet; it undermined a concrete patio and

swimming pool (see Locality 81 and Photo 40). The failure originated in fill. Several erosional gullies originated at the top of the slope, just below a group of vacant building pads, indicating either improper discharge or ponding of water on the pads.

Noteworthy is a property just west of Locality 81 where a high, concrete retaining wall constructed along with a single residence prior to 1950s tract development has effectively protected the building lot from failure.

Only properties listed by Los Angeles County as damaged are depicted (with round black symbols) as damaged in this slope segment on Plate 1 of this report. The slope portions of some properties on Kenway Avenue in the vicinity of slope failures mapped (in red) also appear to be damaged, depending on the downslope boundaries of the properties. (Locality 81)

Slope segment 3X. This slope segment borders Presidio Drive and a short segment of Stocker Street on the east. It consists of a uniform 1 1/2:1 to 2 1/2:1 natural slope with a height of 50 to 95 feet. The slope is mostly underlain by the Baldwin Hills sandy gravel (Qb). Artificial fill with a 1:1 slope gradient was placed along the top of the slope during development (this fill is not shown, however, on Plate 1, herein). The vegetation on the natural slope includes grass and shrubs while the fill slope is planted with both ivy and large leaf ice plant.

The only slope failure caused by the 1978 and 1980 rains occurred on the 1/1:1 cut slope and consisted of a shallow slump and erosional gullies with a maximum depth of not more than 3 feet.

Summary of Causes of Slope Failure

Evaluation of damaging slope failures in Sub-area 3 indicates that they have resulted from one or more of the following causes:

(1) Improper placement of artificial fill: During the main period of development of the Baldwin Hills in the 1950s, grading was less regulated than today and grading practices reflected this lack of regulation. Thus, whereas available records indicate that interior portion of fills were correctly compacted to at least 90% of the maximum dry density, field observations for this study indicate that surficial portions of fills may not have been properly compacted, which may partially explain the reason for so many surficial failures in fill slopes. Also, it is not known whether emplacement of fills included their being benched and keyed into bedrock as required by proper engineering procedures. Subsidence of several fills beneath building foundations in the sub-area, with resultant structural damage, suggests that additional subsidence of fills at other addresses probably will occur in the future.

(2) Most failures are related to a lack of, or inadequate control of, surface drainage on all types of slopes, including natural slopes. Many large, steep slopes have no drainage devices, such as concrete drains in swales or terraced bench drains. Additionally, many earthen slopes directly below concrete drains in swales are deeply eroded and landslided, and commonly this erosion and landsliding has caused undermining of the drains. This problem can be attributed to poor design of drainage systems or to inadequate cleaning of obstructive, storm-derived debris in drainage benches, which causes damaging overflow. Ponding of water behind obstructive debris in unpaved benches tends to promote saturation of the underlying slope material, eventually leading to soil slips and erosion.

(3) Water from a large number of backyards of residences at the upper edges of slopes has been allowed to flow downslope instead of being diverted away from the slope to streets and storm drains. The resultant heavy sheet flow of water on slopes during rainstorms has contributed to severe erosional problems as well as to soil slips and debris flows.



Photo 27. Closeup aerial view in 1978 showing effects of debris slides and erosion on slope along Stacker Street. Backyards far single family residences at top of slope are endangered by the cutting-back effects of the erosion. Apartment buildings of the base of the slope will be endangered until a wall is constructed to prevent debris from flowing downward into the buildings. (Locality 77, Sub-area 3, Plate 1 and Table 3c.) Photograph by John Shadle provided courtesy of the Los Angeles City Department of Building and Safety.

Sub-Area 4 - Southwestern Area*
(Culver City 90230)
(Slope failure localities 82-89)

Introduction

Sub-area 4 is located at the southwestern edge of the northern Baldwin Hills (see Plate 1). The sub-area lies south of West Los Angeles College and west of Holy Cross Cemetery. Geologic features and damaging slope failures that occurred in the area in 1978 and 1980 are shown herein on Plate 1. The damaging slope failures are mainly limited to a residential area of Culver City.

The principal property damage in Sub-area 4 has occurred along the steep western slope of the Baldwin Hills, which is part of a north-northeast trending ridge that borders the flood plain of Ballona Creek. This slope is about 200 feet high and has a natural slope angle of about 30-35° (1½:1). The slope was developed residentially together with its adjoining ridge top to the east between 1952 and 1956. Before development the area was mostly a citrus grove. The slope and ridge top were developed with only slight modification of their natural features, as discerned during this study by interpretation of pre- and post-development aerial photographs. This modification included cutting back of the already steep natural slope to make room for building pads and access roads, but very little artificial fill was emplaced in gullies within the slope.

The steep slopes of the area are underlain mostly by Baldwin Hills sandy gravel (Qb) and underlying Culver sand (Qc) (Plate 1). The contact between Qb and Qc along the steep west-trending slope trends approximately north-northeasterly, reflecting the very gentle south dip (2-4°) of these rock units. Qb is composed of poorly sorted coarse sand and gravel interbedded with sand and sandy, clayey silt and clay. The coarse material is only slightly clay-cemented and, therefore, is easily eroded. Qc constitutes the major rock of the area; it consists of beds of thinly laminated coarse to fine sand; these beds are poorly cemented with clay and also are easily eroded. Resistant Fox Hills relict paleosol (Qf) caps the ridge.

Development Methods

Some parts of the original configuration of the natural slope were retained during development, but most parts that border pads for houses were steepened to 1:1 or slightly greater. A nearly vertical cut was made to develop pads for houses on several adjoining residential properties at the base of the slope. These houses are protected only by a low, unreinforced retaining wall. Study of available building records and aerial photos does not indicate the presence of lengthy fills in Sub-area 4 (which are present in some other areas of the Baldwin Hills), although fill (af) was placed during development along the back edge of many lots at the top of the slope, particularly along Youngworth Road (Plate 1).

The height of slopes between adjacent upslope and downslope residences ranges generally from 30 feet to 75 feet or slightly greater, with the lengthiest slopes occurring between Youngworth Road and Cranks Road. No engineering-designed drainage terraces or benches were constructed during grading for residential pads to control runoff, although still-existing benches for the former citrus groves provide some drainage control for down-slope runoff. None of the cut slopes were benched during residential development.

Selected slope failures are described in Table 3d (in pocket of report).

Slope Segments (4A through 4J)

Slope segment 4A. This segment is bounded by Drakewood Road, Flaxton Street, Ranch Road, and Youngworth Road. It consists of the north part of the main, west-facing slope of the area; it is approximately 60 feet high, with a 1 ½:1 to 1:1 slope gradient. Bedrock of the segment consists of silty sand of the Culver sand (Qc). During development, artificial fill (af) was placed along the upper edge of the slope for grading of building pads along the west side of Flaxton Street. Slope portions of properties along Flaxton Street are planted mainly with ivy; trees are locally abundant. Ice plant grows on the slopes of some properties located along Drakewood Road and Youngworth Road.

Slope failures mapped on Plate 1 comprise soil slips and surficial erosion in both cut and fill slopes. The more serious failures occurred mainly in fill slopes covered with ice plant (see Locality 82 on Table 3d in pocket). These failures were probably caused by improperly compacted fill and improper yard drainage, which allows ponding of water in backyards and consequent overflow down slope during heavy rains. Many of the failures have been repaired with pipe-and-board revetment systems. No damage was reported or observed on the slope where it was planted with a dense growth of trees and shrubs. (Locality 82)

Slope segment 4B. This segment is located between Cranks Road and Youngworth Road. It consists of a steep (1:1) cut slope, 50 to 70 feet high, below a gentler natural slope. The segment is underlain mainly by easily erodible silty sand (Qb). Most properties within the segment are planted with ice plant; some are planted with ivy.

Slope failures mapped consisted of minor soil slips and surficial rills caused by erosion. The most severe damage occurred at 10612 Youngworth Road where slide-off of the ice plant cover and subsequent shallow erosion (less than ½ foot deep), both in 1978 and 1980, caused extensive and costly damage to the 70-foot high, 1:1 back slope of the property (Locality 83, Table 3d). These failures were probably caused by poor drainage control that resulted in extreme, down-slope runoff from a gentler slope above. In addition, gopher holes reported by the owner apparently allowed infiltration of water into the relatively permeable ground surface of the slope, further aggravating its instability.

Most failures in the segment have occurred on properties planted with ice plant. Erosional gullies also were observed in some ivy-covered portions of the slope. Many of the 1978 failures were repaired with pipe-and-board revetment systems which were undermined by the 1980 rains, indicating their inadequacy as a long-term measure to stabilize the slope. (Locality 83)

Slope segment 4C. This segment is bounded by Ranch Road, Telefson Road, and Cranks Road. Most of the properties damaged are located along the west side of Cranks Road. Study of aerial photographs indicates that there is an old, abandoned road located on the slope midway between Lugo Way and Cranks Road.

Grading for tract development in the segment area, which was mainly done in the mid-1950s, generally only slightly modified the configuration of the original slope. The upper portion of the slope was left mostly in its natural state, but the base of the slope was mostly cut steeply back for construction of level pads. Houses on these pads are located east of the intersection of Telefson Road and Bernardo Road.

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Approximately 14 properties within the segment are known to have suffered slope failure damage in 1978 and 1980. Some of these properties, at both the top and bottom of the segment, have had structural damage to houses. The damaging slope failures have consisted of soil slips, erosional rilling, and debris flows. Most of the failures apparently originated at the top of the slope, suggesting that improper yard drainage was an important ingredient of their cause. For example, a level pad on 10730 Cranks Road, above 5714 to 5720 Telefson Road, is reported to have been improperly graded so that water is allowed to flow over the back edge of the yard and down the 1:1 cut slope, resulting in

erosional damage to the slope (see Localities 86 and 88 on Plate 1). Another steep portion of the slope, which lies immediately east of the intersection of Bernardo Road and Telefson Road, has suffered the worst damage in the segment; this damage was caused by erosional effects and soil slips (Locality 87, Table 3d, Plate 1, and Photos 28 and 29). (Localities 84 to 88)

Slope segment 4D. This segment is located between Bernardo Road and Telefson Road. It consists of a cut slope that is steep (45°; 1:1) at the top and steeper (70°), with low retaining walls, at the base. The slope ranges in height from 30 to 50 feet. Most

Photo 28. View north, at the southwest edge of the northern Baldwin Hills, shows a single-family residential property on Telefson Road in Culver City that was inundated in 1978 by debris sloughing, sliding, and flowing from a steep slope of only moderately compacted silty sand and gravel. The house had been constructed just before the 1978 rains. (Locality 87, Sub-area 4, Plate 1 and Table 3d).



Photo 29. View east shows south edge of house in Photo 28 after the adjoining slope was cleaned off and repaired after the 1978 rains. Note that erosion caused by the 1980 rains cut well into the bared bedrock slope. View also shows an apparent angular discordance between beds of the Baldwin Hills sandy gravel (Qb, Plate 1) (parallel to and above the fence top) and underlying beds of the Culver sand (Qc).

properties in the segment are planted with ice plant. The slope segment is underlain mainly by easily erodible, silty sand of the Culver sand (Qc) (Plate 1).

The slope portion of several properties was subjected to damage caused by soil slips and surficial erosional rilling in 1980 but no structural damage was reported (see Locality 89 on Table 3d). Some slope failures may be attributed to improper drainage of yards at the top of the slope. Apparently no damage occurred in 1978. (Locality 89)

Slope segment 4E. This segment is located between Culview Street and Hill Road. It consists of a steep cut slope about 30 feet high planted with ice plant. Six properties were damaged in 1978, mainly by surficial erosion caused by improper yard drainage.

Slope segment 4F. This segment contains a slope which encircles the north side of the cul de sac at Stephen Terrace. The slope has a maximum height of 35 feet, with a gradient of 1:1. The slope is planted mostly with ivy and underlain by gravelly sand of the Baldwin Hills sandy gravel (Qb). No slope damage has been reported in the segment.

Slope segment 4G. This slope segment is located along the south side of Tellefson Road and is the easterly continuation of Slope segment 4D. The highest portion of the slope, about 40 to 50 feet high, is situated at the boundary between Slope segments 4D and 4G, from where the slope decreases in height toward the east.

A bench drain is provided for the slope between apartment buildings on the north side of North Drive, at the base of the slope, and residential houses along the south side of Tellefson Avenue, at the top of the slope. The slope has a 1½:1 gradient below the bench drain and is planted mainly with daisy. Above the bench drain, the slope is steeper (1:1) and is planted with ice plant. A concrete retaining wall 6 to 7 feet high has been constructed at the base of the slope. The southeast portion of this segment is characterized by a 1½:1 slope, about 15 feet high.

There has been no reported slope damage in the segment. However, a pipe-and-board revetment system has been constructed just above the retaining wall below the east end of the bench drain, suggesting that the slope may have failed in the past.

Slope segment 4H. This segment consists of a natural slope along the east side of the sub-area. The slope has a gradient that averages 1½:1, although the south portion is much gentler. The slope is bounded at the top by backyards of single family residences on Esterina Way. No slope damage has been reported or was observed during the field study for this report.

Slope segment 4I. This segment is a relatively flat area that slopes very gently to the south. No potential for slope damage apparently occurs in the segment.

Slope segment 4J. A slope borders Flaxton street on the north. Apparently no damaging slope failures have occurred along the slope.

Causes and Evaluation of Slope Failures

The causes of slope failure that occurred in Sub-area 4 in 1978 and 1980 can be summarized as follows:

- (1) Bedrock underlying slopes is highly erodible.
- (2) Steep graded and natural slopes, mostly greater than 1 ½:1, are steeper than allowed by present building codes.

- (3) There are no drainage devices for runoff control, such as longitudinal slope drains and horizontal bench drains, as specified in Chapter 70 of the Uniform Building Code, which is used now by Culver City to regulate grading.
- (4) Improper vegetation cover: Most slopes are planted with shallow-rooted ice plant, and the majority of slope failures have occurred in these slopes. This shallow-rooted plant builds a thick, mat-like growth when mature; if loose soil of steep slopes becomes saturated during heavy rainfall, it cannot hold the heavy weight of the thick growth; thus the ice plant becomes detached and slides downward. In contrast, very few slopes with a dense growth of shrubs and trees have been damaged by slope failure in Sub-area 4.
- (5) Improper drainage control for building pads at tops of slopes causes surface water to flow to the backyard of residences during heavy rains, where it ponds and then overflows down the back slope. This directly causes failure of slopes or exacerbates already existing problems created by an unstable slope. Evidence for ponding and overflow as a cause of slope failure can be seen at some localities where erosion gullies can be traced from lower parts of slopes upward to backyards at the top. Ponding in backyards may also cause settlement and weakening of the underlying, inadequately compacted fill, and perhaps its failure, as occurred at 10641 Youngworth Road (see Table 3d in pocket for description of damage).

Sub-Area 5 - Central Area * (principally Inglewood oil field, Los Angeles County) (Slope failure localities 90-92)

Sub-area 5 comprises about 2 square miles in the west and central parts of the Baldwin Hills that are developed principally as the Inglewood oil field (Plate 1). The sub-area also includes West Los Angeles Community College, a facility of the Southern California Edison Company, and the site of the former Baldwin Hills Dam and Reservoir. The sub-area is bounded on nearly all sides by residential property. On the east it is partly bordered by a narrow, north-trending strip of property owned by the Los Angeles City Department of Water and Power that contains towers and electrical transmission lines. Most of the sub-area is in unincorporated territory of the County of Los Angeles and under the administrative jurisdiction of the County, including matters relating to building and safety (Figure 3).

A Los Angeles County regional park is planned to include most of the oil field area ultimately as well as the site of the dam and former reservoir (County of Los Angeles, 1975). The park is planned tentatively to grow incrementally by displacing petroleum production facilities as production diminishes.

The oil field area borders the north-northeast trending Inglewood fault on the west and lies partly within the graben that adjoins the fault and partly to the west of the graben (Plate 1, Figure 5, and Photo 16). A report by California Division of Oil and Gas (1974) contains data on the occurrence and production of petroleum in the field, and the field is described by Driver (1943). A geologic investigation of the proposed park area was carried out for the Los Angeles County Regional Parks Commission by Engineering Geology Consultants, Inc. (1975).

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Photo 30. A dirt bike trail showing the first stage in the opening of the ground surface to erosion. The trail has "balded" away the vegetation, exposing the soil to incipient channeling during water runoff that was formerly spread out by the carpet of vegetation, but which now tends to follow the trail. (Locality 92, Sub-area 5, Plate 1.)

Slope stability has not been a major geologic hazard in Sub-area 5 because most of it is relatively sparsely developed with oil wells, roads for access to the wells, and other oil field facilities. Additionally, natural slopes in the sub-area are generally not as steep as those in Sub-areas 1-4, which are developed with residential properties and which have been seriously damaged by landsliding and erosion in 1969, 1978, and 1980.

Perhaps the most significant slope stability problem in Sub-area 5 has been erosion. The effects of erosion in the area range from rilling and piping to deep gullying (Photos 30-33). Erosion has been most pronounced in developed and undeveloped terrain underlain by the Culver sand (Qc, Plate 1), the rock most suscep-

tible to erosion in the Baldwin Hills, which, by unfortunate coincidence is widely exposed in Sub-area 5 (Photo 5). Erosion also occurs in terrain underlain by other rock units of the hills, most of which are also relatively easily eroded. Erosion and piping that has occurred in the soils and weathered bedrock of Sub-area 5 may have been initiated by rodent burrowing (Localities 90 and 91).

With development of the oil field beginning in 1924, many parts of the sub-area were denuded and thus made even more vulnerable to erosion than the original natural terrain. In order to protect the denuded areas of the oil field, tar or oil has been applied to slopes by the oil field operators. Tarred or oiled sur-

Photo 31. Erosion beginning to gully part of the same trail shown in Photo 30. Development of the gully has caused the trail to be abandoned. A new route would create similar results.



faces readily shed water, like a roof, but they are so thin that they tend to break through relatively easily. Thus, where they have not been maintained, such surfaces have been easily cut into by water and destroyed by erosion.

Future development of Sub-area 5 will require adherence to the modern grading code of the County of Los Angeles. This should prevent slopes from being graded in such a way that they yield surficial debris slides and flows and erosional rills similar to the ones that have caused so much damage in parts of the hills that were developed mainly when grading codes were much less sophisticated. In addition, much of Sub-area 5 is included within a "special studies zone" that contains faults which are generally

believed to have ruptured the ground during recent geologic time (Figure 11). Structures built in this zone, therefore, must be designed and constructed to accommodate the potential hazard of fault rupture (Hart, 1980).

Among the potentially hazardous slopes in Sub-area 5 is the west-facing scarp of the Inglewood fault that has been modified by erosion. This slope, which lies along the east edge of the sub-area, contains ancient bedrock landslides, and it also has been partly scarred and weakened by dirt bike trails (Plate 1). The potential problems in disturbing this slope are further illustrated in road cuts along the east side of La Cienega Boulevard, south of where the boulevard crosses the Inglewood fault. These



Photo 32. Inglewood oil field area. Gullying down slope from a paved area caused by water that drained without a prepared channel or conduit. Rock unit eroded is the Baldwin Hills sandy gravel. Note the thin soil mantle. Compared with Photos 30 and 31, note the more irregular, blocky surface of the exposed rock in this scene. Although soft and easily eroded, there is enough clay in this rock to make it much firmer than the Culver sand (Photo 5). Note also the generally blocky character of the dislodged material.

cuts consist of Culver sand (Qc) and fill (af), both of which are highly erodible. Much of the recent erosion on the steepest (1:1) cut and fill slopes in the vicinity of La Cienega Boulevard has occurred because there is an insufficient number of bench drains and because existing drains are poorly maintained. A steep cut along the boulevard that exposes the Inglewood fault commonly yields slumps and muddy debris during heavy rains that partially blocks La Cienega Boulevard (Photo 16). North of the fault, the bedrock consists of siltstone and fine-grained sandstone of the Inglewood Formation (Qi). Because this unit is firmer than Qc, erosion is less of a problem in slopes underlain by it. Soil daylighted in cuts, however, is prone to slumping. When the sub-

area is developed more fully, the scarp along the Inglewood fault, as well as the trace of the Inglewood fault at its base, probably should be left undeveloped or developed as park grounds.

Dirt bike trails at the vacant north end of the Inglewood oil field area illustrate the consequences of destroying the continuity of the vegetation on natural slopes (Locality 92) (Photos 30 and 31). These trails, where gullied, should be filled in and replanted. The oil field area offers an opportunity to experiment with drought resistant plants as agents of slope protection. Some such plants are already well established in the area: *Chrysanthemum frutescens* (marguerite or Paris daisy), for example, an attractive perennial.

Phata 33. Inglewaad ail field area. Depressions shown are coued by the collopse of the roof of a subterranean chonnel. The praces is called piping. This type of erasion can stort in soil crocks or animal burrows, ar it can develap where graund water fallaws faults or artificial barriers such as retaining walls and faoundations.



Sub-Area 6 - Southern and Southeastern Areas*
(View Park, Windsor Hills, and Ladera Heights,
Los Angeles County 90043 and 90056)
(Slope failure localities 93-98)

Sub-area 6 includes the southeastern part and a portion of the southwestern part of the Baldwin Hills. The sub-area comprises unincorporated land of the County of Los Angeles that is developed by the communities of View Park and Windsor Hills on the southeast and the north part of Ladera Heights on the south and southwest.

The terrain of the area generally is much more gentle than that of Sub-areas 1-4, and thus only a small number of damaging slope

failures occurred in 1978 and 1980. These failures consisted of surficial debris slides (including soil slips) and flows and erosional rills similar to, but less spectacular and less damaging than, slope failures in Sub-areas 1-4. The principal slopes that were damaged in Sub-area 6 occur along La Cienega Boulevard, La Brea Avenue, and Slauson Avenue.

Some soil slips were mapped along the east side of La Brea Avenue in Windsor Hills; these failures mostly occurred in cut slopes, especially in road cuts (Localities 93 and 94). In addition, surficial sliding and erosion south of Slauson Avenue, just east of La Brea Avenue, caused damage to residential properties on Orchid Drive at the crest of the slope (Locality 95). Shallow failures also occurred on cut slopes behind buildings (mostly residential) along the west side of La Cienega Boulevard, just north of Slauson Avenue (Locality 96). A shallow slide located on a slope east of a house on Garth Avenue seems to have

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involved improperly placed and inadequately compacted fill; the slide damaged retaining walls constructed on the slope (Locality 97). Some minor soil slips occurred in natural and fill slopes just west of Shenandoah Avenue (Locality 98).

The main factor contributing to the shallow failures in Sub-area 6 is over-steepened cut slopes that do not have adequate surface drainage control devices. Slope failures in the area, however, have not caused serious damage and probably will not cause serious damage during future rains. A general description of remedial measures that might be utilized to stabilize slopes in the area is provided in the final section of the report.

GENERAL EVALUATION OF THE PROBLEMS OF SLOPE FAILURE IN THE BALDWIN HILLS AND RECOMMENDATIONS FOR STABILIZATION OF SLOPES*

Introduction

In this section a general evaluation of the problems of slope stability in the Baldwin Hills is presented, and general recommendations for the stabilization of slopes are made. These recommendations apply not only to slopes that have been seriously damaged by landsliding and erosion but to slopes that have failed only superficially or not at all and which may have a potential for being seriously damaged during future heavy rains. Additionally, slope maintenance, gully erosion control, and fill stabilization are discussed. General conclusions end the section.

General Evaluation of Causes of Slope Failure

The general conditions of individual damaged slopes in the Baldwin Hills have been described and evaluated in the previous section of the report. Based on these descriptions and evaluations, as well as additional information derived from tract development reports and Los Angeles City and County damage reports, the causes of most of the damaging slope failures in the Baldwin Hills are listed as follows:

1. Both natural and graded slopes in several of the developed areas are excessively steep.**
2. Slopes commonly are underlain by easily erodible sandy material.
3. Gopher holes are common in many natural slopes in undeveloped areas and in some slopes within developed areas. These holes facilitate infiltration of water during rainy seasons and thus help to cause deterioration of slopes and add to the chances of their failure.
4. Loose mantles of soil and other surficial material on natural slopes have been "daylighted" during the cutting of man-made slopes, making the loose mantles easily prone to failure.***
5. Fills placed at the tops of slopes or on slopes during tract development may have been poorly compacted and sub-drains were not constructed.***
6. Some fills apparently were placed on slopes that were not benched; benching helps prevent fills from gradually slipping

ping downward along the surface on which they are placed.

7. Many houses at the tops of slopes are close to the slope edge and, although this closeness in itself may not have contributed directly to slope failure, the occurrence of slope failure at the tops of slopes generally has resulted in more extensive damage to the houses than it would have if the houses had been set back from the edge.
8. Drainage from building pads is so poorly controlled that water is either ponded in backyards or allowed to flow over the back edges of pads and down adjoining slopes. In addition, many buildings do not have proper roof gutters, which further aggravates drainage problems.
9. Graded slopes lack drainage terraces or benches.**
10. Retaining or slough walls were not properly designed. In addition, many properties at the bases of slopes do not have slough walls and thus are vulnerable to debris damage.***
11. Slopes are not planted with proper vegetation cover. In addition, frequent irrigation of vegetation keeps it from developing deep roots needed to "anchor" the slope.

Recognition of Potential Problems

The earmarks of past slope failure, including displays of erosion, slumping and structural damage, are generally obvious. The earmarks of instability of undamaged or slightly damaged slopes that may lead soon to serious damage during heavy rains, however, are generally very subtle. In fact, slopes of many undamaged properties in the vicinity of damaged properties may give little indication that they will fail during future heavy rains. At only a few localities in Sub-area 2 (Plate 1) does cracking in the vicinity of "incipient slumping" apparently foretell additional serious slope failure likely during future rains. For slopes that are shown on Plate 1 to have suffered damage, caution or action is advised based on evaluation of the observed landforms, of seepage, or of other factors noted in analyses, and on comparison of conditions of undamaged slopes with those slopes already known to have suffered damage.

Reconstruction of Slopes and Accompanying Retaining Walls and Drainage Devices That Have Failed

Following are discussions of methods of repair and reconstruction of slopes that have failed, including application of engineered fill and slope surface covers, slope flattening, and construction of revetment systems. Also discussed are the use of retaining walls, drainage devices, and vegetation covers. **** Figure 15 illustrates the general use of measures that can be utilized to alleviate slope instability in the study area.

Slope Repair

Application of engineered fill. When slopes have been damaged by surficial landsliding, the material that slid and adjacent, unslid but weakened surficial material can be removed down to bedrock and replaced with compacted, engineered fill (Figure 16, item 2; Photos 34 and 35). This fill should be composed of granular materials, with a reasonable amount of binder such as

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**Illustrated in Figure 13

***Illustrated in Figure 14

****In the previous section under Area 2, stabilization methods recommended for individual slopes are symbolized as follows: E, Engineering (engineered fill and other slope covers, retaining walls, revetment and drainage systems and so forth); V, Vegetation.

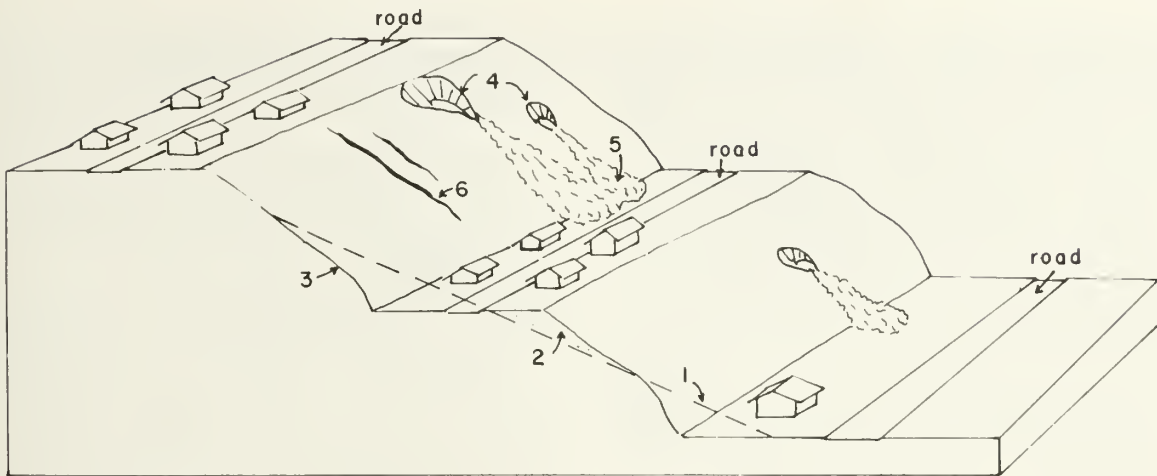


Figure 13. Typical slope resulting from grading during tract development in the 1950 s in the Baldwin Hills area. Natural, predevelopment slope (1) was steepened by fill placement at top (2) and cutting at base (3). Drainage benches were generally not provided. Cutting of natural slope commonly exposed loose, poorly indurated (poorly hardened) sandy bedrock. Fill may not have been adequately compacted and provided with subdrain devices. Slope failures common in such slopes are soil slips and slumps (4), debris flows (5), and erosion rills and gullies (6). (Not drawn to scale.)

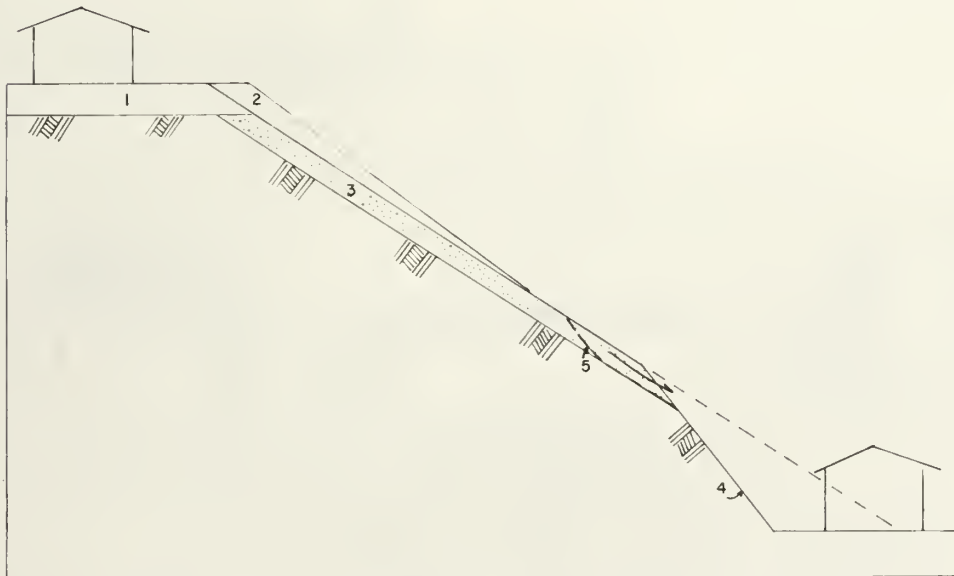


Figure 14. Diagrammatic cross section illustrating slope instability conditions that exist in residential areas of parts of the Baldwin Hills: (1) unstable wedge of the right corner of the fill placed during grading may fail due to gravitational movement if not properly benched or retained; (2) fill dumped over the top of slope during grading operation and not compacted adds to the unstable conditions; (3) slope mantle of soil, colluvium, and weathered bedrock is vulnerable to sliding; (4) cut at the toe of the slope made during tract development makes the unsupported slope mantle material above the cut vulnerable to creep, shallow slumps, and soil slips (5). Material in slips and slumps can slide or flow to base of slope and cause serious damage. (Not drawn to scale.)

silt or clay, which are compacted to at least 90% or better of maximum dry density. In order to be effectively emplaced, the fill should be keyed and benched into firm bedrock. Subdrains are necessary behind many engineered fills in order to prevent buildup during rainy seasons of hydrostatic pressure resulting from water perched in the fill and/or underlying bedrock.

If the bedrock at the site where the engineered fill is emplaced does not contain sufficient binder, the fill made from it may be subject to erosion, even if properly compacted (Photo 35). To alleviate this problem, proper fill material can be hauled in to the site. If this is not practicable, portland cement can be mixed with on-site soil. This soil-cement mixture can be very effective as fill in preventing erosion and surficial slope failures, if properly designed, especially in slopes that are $1\frac{1}{2}:1$ ($33\frac{1}{2}^\circ$) or steeper. In some rare cases, soil-cement fills also have been subjected to erosion. A disadvantage to this type of fill is its barren appearance, as the soil-cement mixture does not readily promote plant growth (Photo 34).

Buttress fills and shear keys are types of earth fill which are placed, respectively, at the base of slopes or within slopes to improve the stability of unstable or potentially unstable slopes. This method requires sufficient accessibility and space for heavy equipment; therefore, it has only limited usefulness in already developed residential areas.

A possible remedy for erosion or instability along wide slope sections, where sufficient working room is available, is *Reinforced Earth*^{*}. This is a patented technique that utilizes reinforcing strips within a granular backfill together with a facing that consists of precast concrete panels. This may be useful for reconstructing or modifying unstable slopes along roadways and may

be a particularly appropriate measure along La Cienega Boulevard (Sub-area 5) where the local bedrock may meet the special backfill specifications. The costs and benefits of this technique should be compared with conventional retaining walls.

Slope surface covers. Erodible soil and other earth material on steep slopes may be stabilized by covering the slope with gunite (a type of portland cement concrete that is sprayed) (Photo 36). In placing a gunite cover, proper design of the cover and back drains is necessary in order to maintain the integrity of the gunite. Also, gunite may not bond satisfactorily to certain parts of the rock units of the Baldwin Hills, including siltstone of the Inglewood Formation (which may be too expansive) and Baldwin Hills sandy gravel (which may be too loose and therefore not satisfactorily cohesive). It appears that the gunite in Photo 36 was sprayed onto a series of inverted, U-shaped metal rods that have been driven into the ground in order to create a firm bond. In addition, the application of gunite cover has a disadvantage in that it prevents widespread planting except in planter wells in the cover or in planter boxes.

In addition to gunite covers, building blocks can also be utilized to prevent erosion. The utilization of building blocks can be attractive because the holes in the blocks allow vegetational growth on the slope (Photo 37).

Clear plastic sheeting is a very expedient form of cover that can be used to temporarily protect a slope from further erosion before or during repairs and replacement of vegetation. Black plastic should be avoided because it prohibits the passage of light to vegetation and thus may cause the vegetation to die if the plastic is left on a slope for a lengthy period of time.

^{*}*Reinforced Earth* is a registered trademark for a construction material patented by the Reinforced Earth Company, 3990 Westerly Place, Suite 210, Newport Beach, California 92660.



Photo 34. View south in cul-de-sac of Crestview Road in Culver City, in northwestern Baldwin Hills. View shows slope that failed in 1978 as restored with fill and soil cement before the 1980 rains. The newly repaired slope suffered no damage in 1980 even though it was bare of vegetation. House shown on top is on Howardview Court. (Locality 6, Sub-area 1, Plate 1 and Table 3a.)

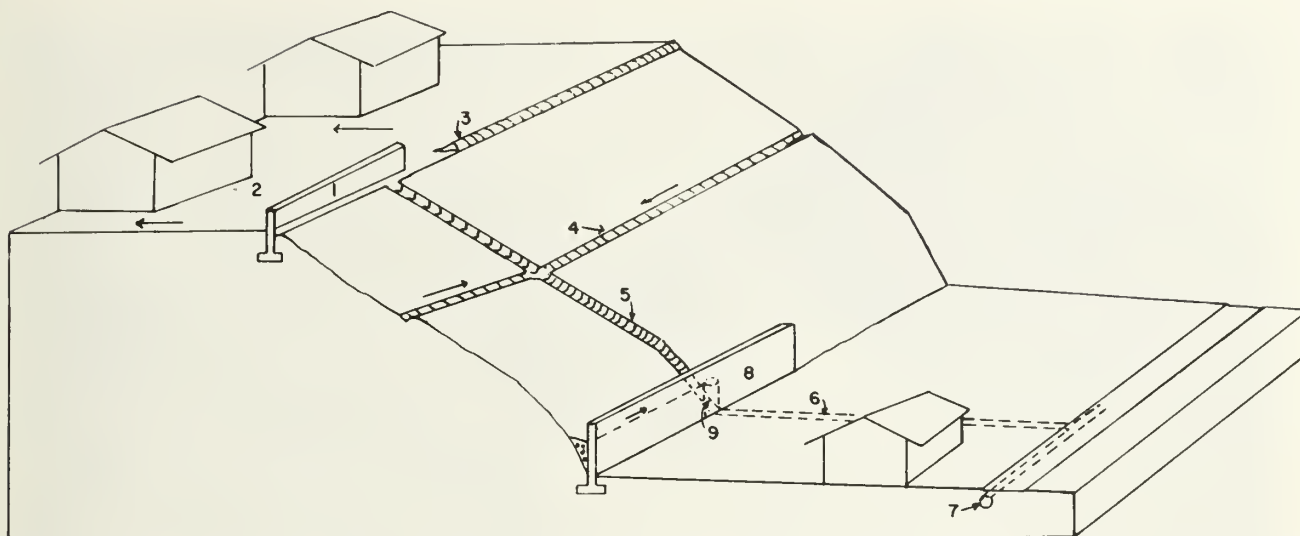


Figure 15. Diagram illustrating measures that can be utilized to alleviate slope instability in the study area: retaining wall (1) may be constructed to protect the property from lateral movement of fill wedge; (2) building pad can be regraded and backyard drainage diverted to street (arrow indicates correct direction of surface drainage); a berm (3) can be constructed at top of slope to prevent water from draining down slope; a bench drain (4) and slope drain (5) can be constructed on the slope to intercept and collect rain water falling directly on the slope surface and to discharge it through an underground pipe (6) into the storm drain along the street (7). A slough wall (8) can be constructed at the toe of the slope to intercept debris flows. Compacted fill should be placed behind the wall and graded so that flow (see arrow) is diverted into a drain-pipe (9) that feeds the outlet pipe (6). (Not drawn to scale.)

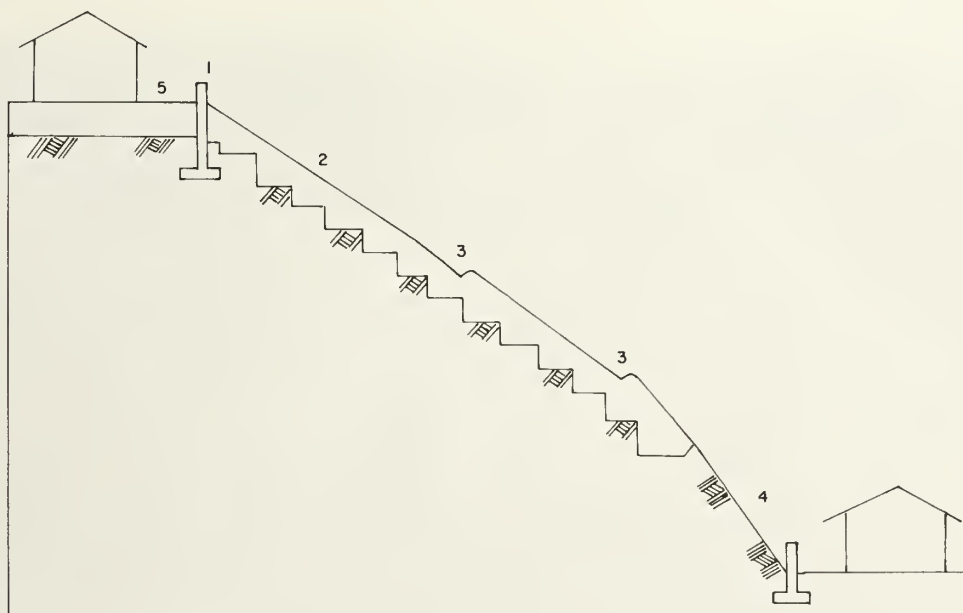


Figure 16. Diagrammatic cross section illustrating alternative remedial measures utilizing engineered fill to stabilize slopes in residential areas of the Baldwin Hills: (1) construction of properly designed retaining wall and drainage devices (such as granular backfill and drain pipe behind the wall and weep holes in the wall); (2) loose soil and slide debris are removed, stabilization fill should then be properly keyed and benched into firm bedrock as shown, and adequate subdrains provided. For steep slopes, soil-cement fill may be desirable. (3) Gunite or concrete bench drains that divert water to discharge outlet are constructed. (4) Retaining or slough wall, with adequate freeboard and drainage devices, may be required at the toe of a cut slope, particularly if the slope material is poorly consolidated. (5) Surface water flow on building pad should be directed away from the slope to the street, and water should not be allowed to flow from the pad down the slope. (Not drawn to scale.)

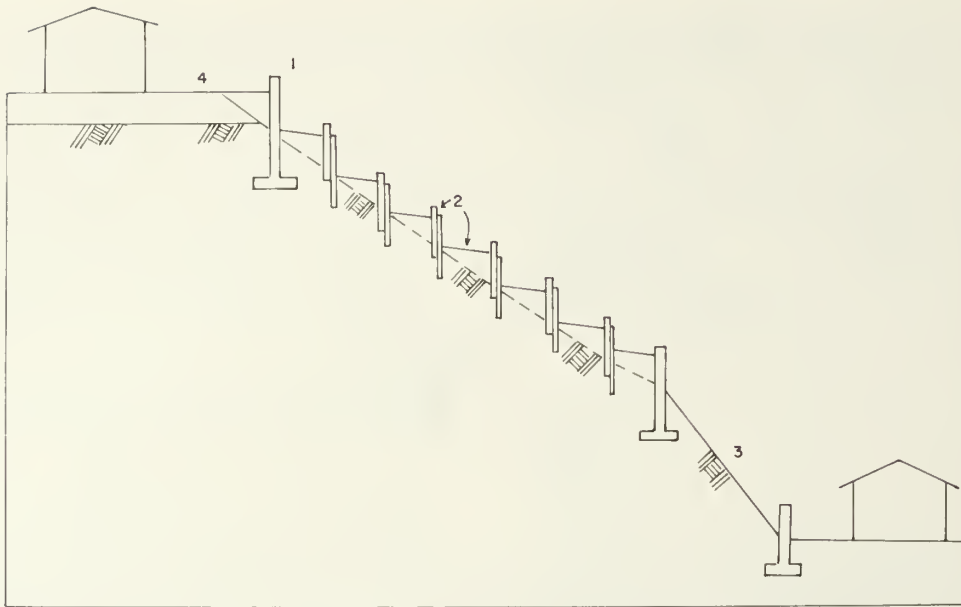


Figure 17. Diagrammatic cross section illustrating alternative remedial measures utilizing a revetment system to stabilize slopes in residential areas of the Baldwin Hills: (1) Construction of retaining wall—foundation of retaining wall should be properly designed and placed in firm bedrock (coissons or piles are frequently used). Permeable materials and proper drainage devices and relatively impervious surface blanket should be placed behind retaining wall to reduce hydrostatic pressure. (2) Retention structures—these generally consist of vertical pipes and boards. Pipes are driven into competent bedrock; back fill placed behind boards should be compacted and provided with proper surface drainage devices and proper slope vegetation cover. (3) Cut-slope should be properly planted and stabilized by retaining structures which should have adequate freeboard and proper surface drainage device to prevent water/mud flow damage to property. (4) Surface water flow on the building pad should be directed away from the slope to the street, and water should not be allowed to flow from the pad down the slope. (Not drawn to scale.)



Photo 35. View east in February 1981 shows steep slope on east side of Cloverdale Avenue that was reggraded with a retaining wall constructed at the top of the slope after the 1980 rains. The slope was seriously damaged by rains in 1978 and then expediently repaired with board and pipe revetment structures that were undermined by runoff during the 1980 rains. Note that erosion accompanying the 1981 rains has caused some rilling damage to slope. (Slope segment 2-0.)



Photo 36. View south on Don Milagro Drive shows the base of a steep slope with a partial cover of gunite as well as board and pipe revetment structures. (Slope segment 2P.)



Photo 37. Illustration of use of building blocks for slope protection. Lower view illustrates how vegetation fills in among blocks, making an attractive slope. Locality is not in the Baldwin Hills. *Photograph courtesy of County of Los Angeles.*

Slope flattening. Where natural or man-made slopes are unstable at their present angle, stability often may be achieved by trimming the slope to a flatter angle. This technique requires ample vacant area at the top of the slope, a condition which cannot be met in many of the residential areas of the Baldwin Hills. The technique might be applied, however, as a remedy for a "daylighted" soil. This occurs where a steep cut slope (usually 1:1) has intersected a natural slope, exposing the soil layer at the top of the cut to possible sliding (item 5, Figure 14).

Soil failures have occurred repeatedly in the study area because daylighted, rain-saturated colluvium is too weak to stand during heavy rains in slopes that are commonly as steep as 1:1 (45°). Usually these failures do not involve the underlying bedrock. By trimming only the soil portion of the slope to a stable configuration, future soil failures might be avoided by using only a minimum of new grading. Where natural slopes are too steep or where there is insufficient space available for flattening, re-

taining walls should be used at the point of daylighting to support the soil (see "Retaining walls").

Construction of revetment systems. A revetment system is generally a less effective but also a less costly method of slope stabilization which is generally applied as a temporary repair measure for damaged slopes (item 2 on Figures 15 and 17). Damaged slopes can be superficially repaired and stabilized with many types of revetment structures, such as board and pipe structures (batter boards) (Photos 38 and 39), railroad ties, poured-concrete walls, concrete-block walls, and other landscape devices. Figure 17 illustrates the method commonly used. For board and pipe systems, pipes are driven vertically into firm material, generally bedrock, to a depth sufficient to anchor them. Railroad ties or redwood planks are then placed so that they are supported by the pipes. Suitable materials are then backfilled against the planks and compacted to at least 90% of maximum



Photo 38. View east on east side of Cloverdale Avenue. Upper part of photo shows expedient board and pipe revetment structure (A) on steep cut slope. Structure has temporarily prevented erosion damage to slope, as has occurred on bare slope to the north. Lower part of photo shows retaining walls and accompanying structures (B) that drain water to street. (Slope segment 2-0, Sub-area 2.)

dry density. Ideally, the retaining boards or planks should have adequate freeboard (height above the finished surface of backfill) so that the structure can also function as a debris or slough wall. Subdrains within the backfill should also be considered in order to reduce hydrostatic pressure and seepage erosion. Photo 38 illustrates a less sophisticated system of board and pipe revetment structures, whereas Photo 39 illustrates a more sophisticated system. Figure 18 illustrates the use of a combination of engineered fill and revetment structures to stabilize a slope.

Concrete block and poured concrete walls also have been constructed on slopes, particularly at property lines (located generally at the middle of slopes) to prevent potential debris flows originating on the up-slope properties to cause damage to the down-slope properties (Photo 39).

Retaining Walls

Many slope failures in residential areas of the Baldwin Hills have occurred at the tops of slopes and have resulted in extensive damage not only to structures located on building pads at the tops of the damaged slopes but also to structures at the bottoms. Many failures at the tops of slopes are the result of poor backyard drainage, which causes ponding in backyards and resultant damage particularly where the backyards and adjoining slopes are underlain by fill. Poor backyard drainage causes rain water either to pond and filter down into the fill or to flow over the back slope. Either situation may directly or indirectly cause slopes to fail. Poor backyard drainage resulting in ponding generally is a result of the improper grading of pads during tract development (Figure 13). Proper grading tilts pads slightly toward streets so that drainage is forced in that direction and ponding and flow over the back slope are prevented.

As discussed in the two previous sections of this report, many fills in the Baldwin Hills may have been improperly compacted. Improperly compacted fills in combination with adjoining steep slopes have failed during heavy rains when the fills have become saturated with water. To alleviate this problem, the fill wedge bordering a slope at the back edge of a pad should be stabilized. However, removal of the old fill and its replacement with properly compacted fill may not only be impractical but costly. The problem of an improperly compacted fill at the top of a slope, therefore, can generally be partially solved by construction of a retaining wall to provide support to the fill. Such walls should be properly designed to perform under each unique set of soil and geologic conditions. The wall footings should be in firm bedrock and the wall should be designed to withstand lateral or active pressure exerted by the material that is to be retained. Cast-in-place concrete walls can be utilized for thin fills but deep caissons or columns may be necessary for thick fills.

Backfill behind retaining walls should consist of relatively permeable, incompressible soil which should achieve at least 90% relative compaction. If the fill is properly designed and emplaced behind the wall, along with proper subdrain devices, water will drain through the fill. If water does not drain properly, hydrostatic pressure can build up seriously behind the wall. Additionally, a cover of impervious soil material should be placed on the fill to prevent infiltration of water down into the fill and the bedrock below it.

In addition to supporting weak fills at tops of slopes, retaining walls can be constructed at bottoms of slopes to support new engineered fills. As a sole slope stabilization measure, retaining walls can also be used to support slopes underlain by weak soils or bedrock weakened by faulting or weathering. Photo 40 shows a retaining wall under construction.

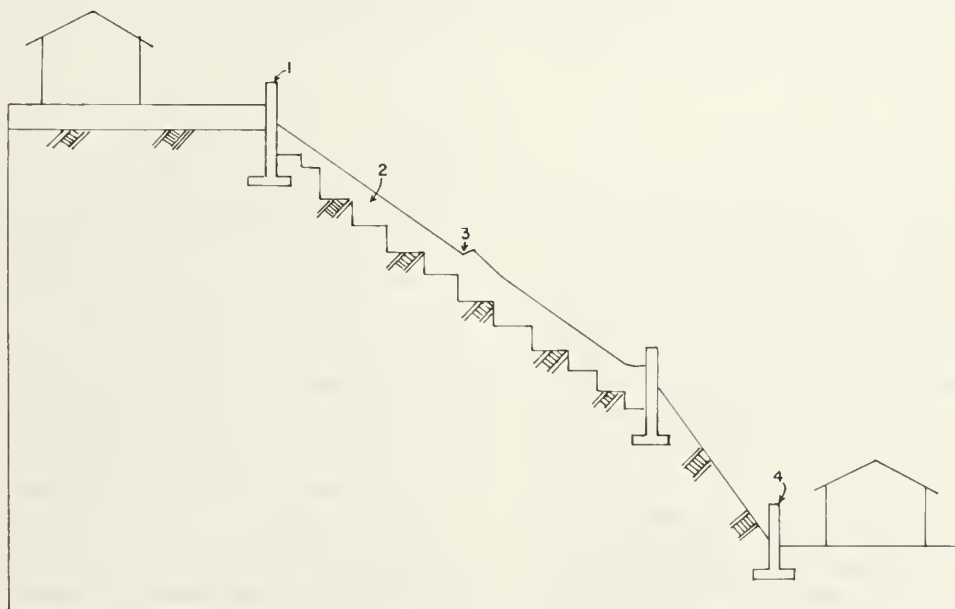


Figure 18. Diagrammatic cross section illustrating alternative remedial measures utilizing a revetment system and engineered fill to stabilize slopes in residential areas of the Baldwin Hills: (1) Properly designed retaining wall and drainage devices (such as granular backfill and drain pipe behind the wall and weep holes in the wall). (2) Loose soil and slide debris are removed, stabilization fill is then properly keyed and benched into firm bedrock as shown, and adequate subdrains should be provided. For steep slopes, soil-cement fill may be desirable. (3) Gunite or concrete bench drains that divert water to discharge outlet are constructed. (4) Retaining wall with adequate freeboard and a drainage device to prevent downhill earth movement and water/mud damage to property are constructed. (Not drawn to scale.)



Photo 39. View northwest in February 1981 of slope in back of apartment buildings on Don Tomoso Drive showing board and pipe revetment structures constructed after 1978 rains to protect slopes. Note mid-slope retaining wall on property to left. Note also expedient use of plastic sheeting together with other slope stabilization measures. (Locality 74, Sub-area 3, Plate 1 and Table 3c.)

Drainage Devices

The quality of slopes and accompanying retaining walls are not the only factors in making slopes stable. The success of a repair effort is usually determined by whether it has properly controlled runoff and how well the slope is subsequently maintained. Therefore, surface and near-surface drainage devices generally are the decisive factors in stabilizing a slope because the performance of these devices determines whether the soil becomes oversaturated and exceeds its liquid limit, whether excessive hydrostatic pressure will be exerted against retaining structures, and whether runoff down the slope surface will gain enough velocity to cause erosion.

Surface drainage devices on slopes consist of terraced drainage benches and down-slope drains, as illustrated in Figure 15. When the height of a slope is great, drainage benches, terraces, or swales should be established on the slope at vertical height intervals specified in the applicable grading code or as determined by a soils engineer. Water diverted along such benches is collected into a downslope drain, possibly also using sub-surface (sub-) drains, and eventually discharged into the street or into storm drains. To prevent bench drains and slope drains from being eroded, a gunite or asphalt surface is usually placed on them.

Drainage benches and slope drains are important also for large, unmaintained natural slopes above developed areas so that

runoff during heavy rains can be collected and channeled safely through natural drainage gullies or swales. Such gullies or swales can be lined with concrete to prevent their further erosion.

In addition to drainage devices on slopes, precautionary measures should be taken to control drainage for building pads on the tops of slopes. Proper surface drainage control of building pads ("positive pad drainage") is essential in maintaining the integrity of underlying or adjoining fills. No rain water should be allowed to pond on pads; it should drain freely to existing streets and drains, using a combination of proper grading and surface or near-surface drain systems. For a backyard that does not have a retaining wall provided with freeboard to stop overflow, a diversion berm should be maintained along the top of the slope so that water will not flow over the edge (Figure 15).

To provide effective, economical slope drainage systems, it is necessary that such systems be constructed across entire slopes that generally include several or more individual residential properties. Slope-wide systems can properly control possibly voluminous runoff from swales and gulches that probably could not be controlled properly by systems constructed on individual properties. Slope-wide drainage control programs could be implemented by local jurisdictions, including the cities of Los Angeles and Culver City, the County of Los Angeles, or by local homeowners' associations or assessment districts, including geologic hazard abatement districts (see Appendix VI).



Phata 40. Retaining wall under construction in February 1981 at top of slope on south side of Stocker Street, just east of Valley Ridge Drive. Houses are on Kenway Avenue. Wall is designed to protect two properties at top of swole that has been a source of debris slides and flaws. Out af view slightly to the west is a strang retaining wall built during construction of adjoining house on Kenway Avenue in late 1951 or early 1952. (Locality 81, Sub-area 3, Plate 1 and Table 3c.)

Vegetation Cover

Proper vegetation cover plays an important role in the stabilization of slopes and may be the only control needed to prevent excessive erosion in slopes of small height. Ideal plants for slopes are ones that grow fast, have deep, strong root systems, and are drought resistant and fire-retardant. In addition, they should not create such a dense cover that evaporation of moisture from the ground is hindered excessively.

A pamphlet entitled "Fire Retardant Plants for Hillside Areas," which was compiled by personnel of the Los Angeles County Department of Arboretum and Botanic Gardens and the Los Angeles County Forester and Fire Warden, Los Angeles County Forestry Division, provides a list of plants suitable for protection of slopes. The approved plant list for hillsides in the City of Los Angeles is printed as part of the City's "General Grading Requirements." Based on available records and field observations by investigators for this study, shallow-rooted, large-leafed ice plant has been notorious as a contributing factor to slope failure where it has been planted, and it should therefore be avoided as a cover. It is shallow-rooted and builds up into a thick, heavy mat that impedes evaporation and may break loose and slide during heavy rain because of its weight.

Planting of a proper vegetation cover on many existing slopes in the Baldwin Hills may be difficult because of the excessive steepness of these slopes. Jute matting may be used to assist planting. Heavy, woven jute mesh can be rolled over the slope and stapled to the ground. When properly installed, it cannot be lifted by flowing water, wind, or growing vegetation (Amimoto, 1978).

Because irrigation systems are required to sustain many types of vegetation, caution should be exercised in their use and maintenance so that overwatering of slopes does not occur. Overwatering, especially in the winter months, can amplify the effects

of heavy rainfall, and thus increase the possibilities of slope failure. Also, too frequent watering tends to keep roots near the ground surface instead of allowing them to grow deeply, which is encouraged by less frequent watering. A deep root system for the vegetation cover acts somewhat as an anchoring system for the slope, reducing the possibilities of soil failure.

Modification of Slopes That Have Not Failed in Order to Reduce the Hazard of Their Possible Failure

There are several recommended corrective measures that can be taken to alleviate the potential for the occurrence of slope failure and its resultant damage to properties. These measures include (1) control of moisture infiltration and runoff, (2) chemical stabilization, (3) slope flattening, and (4) emplacement of slough walls.

Control of Moisture Infiltration and Runoff

Surface runoff and water content within the soil or bedrock are the key factors in determining whether slope failure may occur. Excessive infiltration of water into the ground will lead to saturation of soil, which in turn reduces the shear strength of soil. Uncontrolled runoff will bring about damaging erosion and debris flows. Moisture infiltration and runoff can be controlled through proper planting of a vegetation cover on slopes, elimination of rodent activity, use of proper drainage devices, application of a gunite cover, and construction of revetments or retaining walls. Of these methods, vegetation and gunite covers, revetment systems, retaining walls and drainage devices have been discussed earlier in this section.

Gopher holes are common in the Baldwin Hills, particularly in natural slopes (Photos 41 - 43). These holes and their accompanying network of underground tunnels facilitate water penetration into the ground, promote erosion, and decrease the shearing strength of the soil. In addition, the activities of gophers adversely affect needed plant growth on slopes. It is recommended strongly, therefore, that rodent abatement programs be implemented in the Baldwin Hills to control the activities of these animals. To be effective, abatement programs should not only include developed areas but adjoining undeveloped areas as well. If gophers are abated only in a developed area, new gophers from adjoining undeveloped areas that are not abated will soon renew the digging and tunneling problems in the abated area. In addition, gopher abatement programs should be followed up with grouting programs to fill-in abandoned burrows and restrengthen weakened slopes in the developed areas.

Throughout the study area there are sites where deep saturation by water into fill, soil, and bedrock has been identified as the root cause of slope stability problems. At many additional sites, thick deposits of colluvium on slopes constitute probable future problems unless deep saturation can be prevented. Special efforts must be made to control infiltration and to remove already existing excess ground water where seepage or slope failures have been observed at the base of artificial fills, where fills are experiencing damaging settlement, and where dangerously thick colluvial deposits or known landslide masses are perched above houses and roads.

Water infiltration in these moisture-sensitive areas can be reduced by using landscape vegetation that requires a minimum of irrigation and hence reduces considerably the amount of irrigation water introduced into the ground. Also, it must be re-emphasized that positive lot drainage is essential in order to prevent water from standing on the ground surface and soaking into moisture sensitive areas. Problem areas that become, or remain, saturated despite surface control efforts need to be dewatered by measures such as installation of horizontal drains in order to reduce the possibility of slope failure or further fill settlement. The application of plastic sheeting during the rainy season may be advisable if the slope is saturated to the point where additional infiltration will reduce shear strength and cause shallow debris slides and flows.

Chemical Stabilization

In addition to the use of soil cement and chemical grouting to strengthen weak soil or fill, as discussed elsewhere in this section of the report, techniques also exist for the use of chemicals to stabilize bedrock landslides. These techniques, although not applicable for stabilizing all bedrock landslides, have an advantage in that they do not require expensive, massive grading. Their use might be considered for treating several features in residential areas mapped tentatively for this study as ancient bedrock landslides if detailed investigation of the features shows that they are landslides with a potential for massive failure (see Plate I and



Photo 41. Gopher holes in rubbly soil. Note how holes tend to join and open up along fractures. This is a common cause of "piping" (Photo 33). Burrowing rodents should be trapped or gassed but not flushed out with water. The use of water is not apt to succeed and may start erosion through piping. In Qb and Qc units, rodent holes commonly extend well into the weathered bedrock underlying the soil. (Sub-area 5.)

Figures 7a and 7b). Chemical additives may also be used to strengthen some clayey soils.

Slope Flattening

Slope flattening, which has been discussed earlier in this section, is a technique that may be used as a stabilization measure for a "daylighted" soil. Because such failures have occurred repeatedly in the study area they represent a continuing hazard that should be corrected.

Emplacement of Slough and Deflection Walls and Debris Fences

To protect properties at the toe of potentially unstable slopes, retaining or slough (debris) walls can be constructed. These walls should project vertically above the slope to such a height (have adequate freeboard) that debris flows will not overtop them. Such walls also should be designed in such a way that debris and water accumulating behind them is diverted to the street either through a diversion ditch or through large diameter drains (see Figure 15). In addition to proper engineering design of such walls and their foundations, adequate sub-surface drainage of the permanent earth material behind the walls should also be provided.

On the north flank of the hills, in Slope segments 2C, 2E, and 2I of Sub-area 2, the natural slopes possibly could yield large debris flows during heavy rains that could damage properties

located below the slopes. A protective earth embankment or diversion berm and channel could be constructed to protect these properties.

Where houses are directly downslope from a thick buildup of soil and colluvium on a natural slope, and perhaps an unstable fill at the top of the slope, the construction of debris fences or deflection walls should be considered. Debris fences are constructed to stop or impede the flow of watery debris, whereas a deflection wall deflects debris around a property and out into a street or into a drainage channel.

Additional Considerations

Gully Erosion Control

Special techniques of erosion control need to be applied to natural gullies or drainage channels which, in the Baldwin Hills, are dry for much of the year but during storms can carry a considerable amount of water with damaging erosional power. The eroded material from these gullies has been deposited in backyards and streets, including La Cienega Boulevard. The inundation of streets during heavy rains creates a serious hazard. Since these gullies generally receive runoff from much larger areas than just the slopes previously discussed, it is not practical to divert the runoff away from the gullies. Rather, the gullies need to be protected from the erosive forces by protective paving,



Photo 42. View shows gopher holes that have already appeared in a newly graded bedrock slope for a new house on El Mirador Drive, Los Angeles City. The house was not yet completed when this photo was taken. (Locality 47, Sub-area 2, Plate 1 and Table 2b.)



Photo 43. Closeup view of gopher holes shown in Photo 42. The scene emphasizes the need to control gophers in order to maintain slope stability.

concrete channels, or velocity reduction structures so that storm flow can be conducted safely to streets or storm drains.

In some places, such as the lower gullies of Slope segment 2V of Sub-area 2, erosion might be prevented in the future by construction of erosion check dams in the gully mouths adjacent to La Brea Avenue. If the gullies are then backfilled, future headward erosion could be prevented because of the artificially higher base level created. The *Erosion and Sediment Control Handbook* (Amimoto, 1978) is a useful reference for erosion problems.

Fill Stabilization

The subject of fill stabilization is discussed separately from that of slope stabilization because many of the problems associated with artificial fills exist independently of slopes. Many residences and other structures have suffered distress due to vertical settlement of fills on which they are founded. The basis for this settlement may be looseness of the fill material caused by inadequate compaction when the fill originally was emplaced or the basis may be looseness caused by many years of weathering of the fill and burrowing in it by animals. If moisture is allowed to saturate the loosened fill material, the fill begins to consolidate, often unevenly, with a resultant uneven movement of structures built on the surface, perhaps causing them to crack apart if the settlement is not stopped. Although some ground moisture exists in all fills, the increased amount of damage caused by settlement following heavy storm periods is an indication that rainfall has been a prime cause of over-saturation of fills and its consequent effects.

In order to alleviate the problem of settlement, the amount of moisture entering the fill must be controlled, and excess moisture already in it should be removed (for methods, see "Control of Moisture Infiltration and Runoff"). In addition, the overall strength of the fill must be improved. Where accessibility is good and a lot is not yet developed, a shallow fill that has settled can be removed and replaced using proper compaction methods. Where it is not possible to remove and replace a fill, either the fill must be strengthened in place by such a technique as compaction grouting, or the foundations of structures built on the fill must be extended down through it to a firmer foundation material.

Slope Maintenance

Effective slope maintenance programs are the key factor in preventing future slope problems. Such programs should include inspections prior to each storm season by trained inspectors to ensure that all drainage devices are unobstructed and fully functional. One defective or unmaintained portion of a drainage system can have a deleterious effect on the entire system and possibly lead to serious slope failure that could damage several properties. Such inspection programs should function much like presently existing brush clearance inspections for fire hazards, using the authority of local governments or assessment districts to ensure compliance with the goals of the program. A rodent abatement district also should be organized to keep the gopher problem under control.

In such programs, cooperation of individual property owners is indispensable. Unless otherwise arranged, it should be the responsibility of individual property owners to keep slope drains clear throughout the year and to maintain proper roof and lot drainage. It is also the responsibility of individual property owners to minimize landscape watering, especially when fill saturation has been identified as a problem.

Existing guides to slope and lot maintenance have been published by public agencies and private consultants and are listed herein in "References Cited."

General Conclusions

Figure 19 shows that Sub-areas 1 - 4, the principal areas of the Baldwin Hills damaged by rainfall in the past, constitute the principal areas for potential future damage. In contrast, Sub-area 5 consists mostly of nearly flat ground or very gentle slopes that have not had serious problems in the past and do not seem to be in danger of widespread serious failures in the future. Sub-area 6, which now constitutes an oil field, is tentatively planned to be developed as a Los Angeles County regional park when the oil field is depleted. If all or part of the area is developed residentially or industrially, however, it must be graded according to the modern grading code of the County of Los Angeles. Sub-areas 1 - 4 were developed when local grading codes were in their infancy.

Table 4 shows that, of 1,668 residential properties between La Cienega Boulevard and Stocker Street (Sub-areas 2 and 3, Figure 12), and in the southwest part of the hills (Sub-area 4, Figure 12), the most densely developed of the steep-sloped parts of the Baldwin Hills, 345 (20.7%) have been reported or observed to have been damaged by the effects of rainfall. In addition, the Division of Mines and Geology estimates that perhaps 1,546 (92.7%) of the 1,668 properties may risk at least a small chance of future damage from slope failure unless sophisticated measures are taken to stabilize these slopes. Only properties on nearly flat ground appear not to be vulnerable to failure. Even low slopes in Sub-area 3 have suffered minor damage in the past and can be expected to fail in the future.

Although slope failures have been widespread in the hills during the extremely heavy rains of 1969, 1978, and 1980, serious individual failures have occurred even during years when rainfall has not been quite so voluminous, such as 1958, 1962, 1965, 1966, 1967, and 1973. Therefore, if unstable slopes that have not failed are allowed to remain unstable it should be expected that they probably will fail at some time in the future during a year of voluminous rainfall or even during a year of less than voluminous rainfall. It should be pointed out also that as graded slopes become older, they generally tend to deteriorate in strength, as do the accompanying drainage devices and retaining walls, and it is very conceivable that slopes in the Baldwin Hills could fail during a future torrential rainy period even more seriously than they did in 1978, unless proper measures are taken to stabilize them.

Data provided in this report can provide a basis for choosing the most effective measures to stabilize individual slopes. These include descriptive data for damaged slopes in the previous section (including Table 2) and accompanying depictive data for slopes on Plate 1. They also include soil test data listed in Table 2. It must be emphasized, however, that the types of stabilization measures described herein are general and not site-specific. The

choice, design, and construction of stabilization measures for individual slopes or slope segments must be made by qualified engineers, geologists, contractors, and other professionals based on detailed site information and local grading codes, with the approval of local jurisdictional agencies.

The most effective and economical stabilization measures should include all or large parts of entire slope segments which commonly include at least several individual properties and may include 10 to 15 or more properties along both upper and lower parts of a lengthy slope (as shown on Plate 1). In the past, damaged slopes have been repaired only on an individual property basis, whereas measures to repair the damage and truly stabilize the slope should include the damaged property and adjacent, yet-undamaged (but possibly endangered) properties. An ideal way for a community to bring stability to its slopes on a cooperative basis that is long-term financed is to form a "Geologic hazard abatement district" (Appendix VI, herein). The procedure, which was added to State law in 1979, provides a mechanism for issuing bonds to pay the cost of repairs or improvements; it also enables such a district to enter into contracts with private firms or governmental agencies to carry out the purpose of mitigation, abatement, or control of the geologic hazard.

In the Baldwin Hills, a "Geologic hazard abatement district" could be formed on an area-wide basis: for example, to encompass all of the damaged properties on the north side of the hills within the City and County of Los Angeles and Culver City (Sub-areas 1-3). A similar district could include the damaged and endangered properties in the southwest part of the hills, within Culver City (Sub-area 4). A distinctly different type of single district would include just properties within a single slope segment, as these segments are outlined on Plate 1. Such segments range in number from less than 15 properties to more than 35 properties that could make up a single Geologic hazard abatement district. The participants in such districts could not only make sure that slopes are stabilized the most efficient and economical way, but also that they are maintained properly after stabilization. The districts would also help to resolve the problems of change in ownership or inability on the part of individual homeowners to maintain their portions of a slope. The lack of maintenance on a single property, such as the failure to clean a drain, can cause slope instability problems for several nearby properties.

Table 4. Total number of residential properties in the Baldwin Hills between La Cienega Boulevard and Stocker Street (Sub-areas 2 and 3) and in southwest area (Sub-area 4) compared to number of properties damaged by slope failure in the past, and number (including properties already damaged) with apparent potential for possible future damage from slope failure.

Sub-Area	Developed residential properties	Developed residential properties damaged*	Developed properties with apparent potential for at least minor damage in the future
2	464	104 (22.4%)	455 (98.2%)
3	988	193 (19.5%)	935 (94.6%)
4	216	48 (22.2%)	156 (72.2%)
Total	1668	345 (20.7%)	1546 (92.7%)

*1978, 1980, and other years

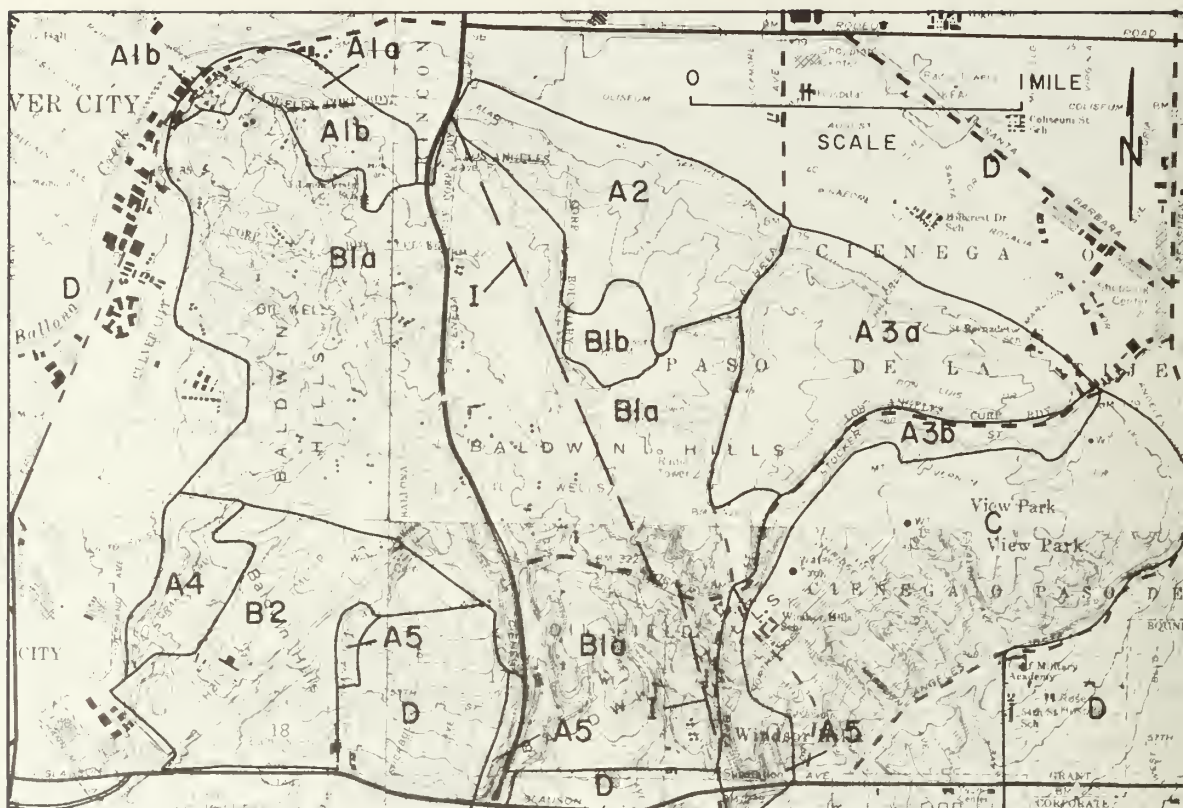


Figure 19. Generalized classification of the Baldwin Hills for propensity to landslides and erosion. See accompanying explanation for details.

Explanation

- A. Residential areas with steep slopes that have suffered widespread damage from landsliding and erosion; such areas, which were developed in the late 1940s and the 1950s before strict, local grading requirements were enacted, will continue to suffer damage from landsliding and erosion until the slope failure hazard is mitigated.
 - A-1a - Los Angeles City; Sub-area 1, Plates 1 and 2 and text
 - A-1b - Culver City; Sub-area 1, Plates 1 and 2 and text
 - A-2 - Los Angeles City; Sub-area 2, Plates 1 and 2 and text
 - A-3a - Los Angeles City; Sub-area 3, Plates 1 and 2 and text
 - A-3b - Los Angeles County; Sub-area 3, Plates 1 and 2 and text
 - A-4 - Culver City; Sub-area 4, Plates 1 and 2 and text
 - A-5 - Los Angeles County; Sub-areas 5 and 6. Plate 1 and text
- B. Land that is developed by Inglewood oil field, Holy Cross Cemetery, and the site of the former Baldwin Hills Reservoir. Landsliding and erosion have been only a minor problem. Possible further development is subject to modern grading codes.
 - B-1a - Inglewood oil field; Plate 1 and text
 - B-1b - Site of Baldwin Hills Reservoir; Plates 1 and 2 and text
 - B-2 - Holy Cross Cemetery; Plate 1
- C. Residential and commercial areas with low, gentle slopes where landsliding and erosion have not been significant problems.
- D. Residential and commercial areas that are essentially flat or where slopes are so gentle that landsliding and erosion are not a significant, potential problem.
- I. Inglewood fault; Principal fault of Newport-Inglewood fault zone in Baldwin Hills. Fault and accompanying modified scarp probably should be left undeveloped. See Plate 1 and text (including Figure 11) for further details.

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*Pamphlets useful to property owners as guides to planting and maintenance of slopes are marked herein by an asterisk. All references listed are on file with the Los Angeles District office of the Division of Mines and Geology, 107 South Broadway, Room 1065, Los Angeles, CA 90012.

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APPENDICES

	Page
I. ASSEMBLY BILL 1571	82
II. RESIDENTIAL AND COMMERICAL PROPERTIES IN THE BALDWIN HILLS DAMAGED BY THE EFFECTS OF RAINFALL IN 1969, 1978, AND 1980	84
III. GLOSSARY OF SELECTED TERMS USED IN THIS REPORT	87
IV. AERIAL PHOTOGRAPHY UTILIZED IN THIS STUDY	90
V. CREDITS FOR TABLES, PLATE I, FIGURES, AND PHOTOS	91
VI. DESCRIPTION OF "GEOLOGIC HAZARD ABATEMENT DISTRICTS"	91
VII. PARTICIPATION IN THIS PROJECT BY DIVISION OF MINES AND GEOLOGY AND DEPARTMENT OF CONSERVATION STAFF, AND CURRICULUM VITAE FOR PRINCIPAL INVESTIGATORS	92
VIII. EXPLANATION OF PREPARATION OF AREAL GEOLOGY PORTION OF PLATE I	93

APPENDIX I

Assembly Bill 1571



AB 1571

— 2 —

Assembly Bill No. 1571

CHAPTER 39

An act to add Section 5105 to the Streets and Highways Code, relating to the Improvement Act of 1911, making an appropriation therefor, and declaring the urgency thereof, to take effect immediately.

Passed the Assembly August 23, 1979

LEGISLATIVE COUNSEL'S DIGEST

AB 1571, Moore. Improvement Act of 1911: geologic hazards.

The Improvement Act of 1911 authorizes the legislative body of a city or county to create assessment districts for paying the cost and expenses of various improvements to property in the district benefited by the work done.

This bill would authorize, under the act, work to prevent, mitigate, abate, or control a geologic hazard, as defined, or to repair damages therefrom and the performance of such work on private property under specified conditions.

The bill would require the Division of Mines and Geology of the Department of Conservation to carry out a slope stability study of the Baldwin Hills area and to report the findings of the study to the Governor, the Legislature, the Los Angeles County Board of Supervisors, and the Los Angeles City Council within 6 months after the effective date of this act.

The bill would appropriate \$85,000 to the Division of Mines and Geology to carry out the study pursuant to this act.

The bill would require, if an assessment district is created to perform such geologic hazard work in the Baldwin Hills area, the assessment district to reimburse the General Fund with interest on the amount expended by the division to carry out the study.

The bill would take effect immediately as an urgency statute.

Appropriation: yes.

James D. Driscoll
Chief Clerk of the Assembly

Passed the Senate March 6, 1980

Darryl R. White
Secretary of the Senate

This bill was received by the Governor this 11th
day of MARCH, 1980, at 2 o'clock P.M.

Roseeta I. Cornick
Private Secretary of the Governor

The people of the State of California do enact as follows:

SECTION 1. Section 5105 is added to the Streets and Highways Code, to read:

5105. (a) Whenever, in the opinion of the legislative body, the public interest or convenience may require, the legislative body may undertake any work necessary or incidental to the prevention, mitigation, abatement, or control of a geologic hazard or to repair damages resulting therefrom.

(b) For purposes of this division, "geologic hazard" means an actual or threatened landslide, land subsidence, soil erosion, or any natural or unnatural movement of land or earth.

(c) Such work may be performed on private property with the prior written consent of the owner thereof, if the legislative body, in the resolution of intention, determines that it is in the public interest to do so.

SEC. 2. The Division of Mines and Geology of the Department of Conservation shall carry out a study of slope stability problems associated with excessive rainfall in 1978 in the City of Los Angeles and the County of Los Angeles, in the Baldwin Hills area, including portions of the communities of Culver City, View Park, and Windsor Hills.

The study shall identify the principal types of slope stability damage and the principal geologic factors that caused that damage. The study shall provide recommendations to enable local officials to determine appropriate site-specific engineering and stabilization measures and costs to mitigate future landslide hazards in the area.

The division shall report the findings of the study to the Governor, the Legislature, the Board of Supervisors of the County of Los Angeles, and the City Council of the City of Los Angeles within six months after the effective date of this act.

SEC. 3. The sum of eighty-five thousand dollars (\$85,000) is hereby appropriated from the General Fund to the Division of Mines and Geology of the Department of Conservation for carrying out the study under Section

2. SEC. 4. If an assessment district is created under the Improvement Act of 1911 (Division 7 (commencing with Section 5000) of the Streets and Highways Code) to perform work specified in Section 5105 of that code in the City of Los Angeles and the County of Los Angeles, in the Baldwin Hills area, the assessment district, within five years after its creation, shall reimburse the General Fund in the amount expended by the Division of Mines and Geology of the Department of Conservation to carry out the study under Section 2, together with interest equal to the amount of interest that would have been earned if the amount expended had been deposited in the Pooled Money Investment Account.

SEC. 5. This act is an urgency statute necessary for the immediate preservation of the public peace, health, or safety within the meaning of Article IV of the Constitution and shall go into immediate effect. The facts constituting such necessity are:

In order that landslide damage in the City of Los Angeles and the County of Los Angeles, in the Baldwin Hills area, including portions of the communities of Culver City, View Park, and Windsor Hills, can be repaired as soon as possible, it is necessary that this act take effect immediately.

Approved 3/11, 1980

Edmund G. Brown Jr.
Governor

9:40 P.M.
ELIZABETH LAQUE

APPENDIX II

**Residential and Commercial Properties in the Baldwin Hills
Damaged by the Effects of Rainfall in 1969, 1978, and 1980**

The following lists of addresses for properties damaged were prepared as follows.

(1) Los Angeles City: addresses for 1969, 1978, and 1980 rain damage were taken from city-wide lists prepared by the Los Angeles City Department of Building and Safety which show for each address the "damage class" (types of damage) and the "estimated valuation" (estimated cost of repair, which ranges on the 1978 list from less than \$100 to more than \$25,000).

(2) Los Angeles County: addresses for 1978 and 1980 were taken from regional lists prepared by the County Department of Building and Safety similar to those compiled by the City of Los

Angeles; the county lists also show types of damage and estimated cost to repair; addresses for properties damaged in the county in 1969 were not compiled.

(3) Culver City: the list of addresses includes both 1978 and 1980 damage; the list was prepared from data acquired during field investigation for this study by the Division of Mines and Geology staff and from a report on storm damage in 1978 in Culver City prepared by the staff of the City.

Copies of the detailed lists prepared by the City and County of Los Angeles are on file with the respective City and County Departments of Building and Safety and with the Los Angeles District office of the Division of Mines and Geology.

LOS ANGELES CITY**1969**

3940, 3969, 4035, 4051, 4055 and 4115 Cloverdale Ave.

4213 Don Alanis Pl.

4519 Don Arturo Pl.

4216, 4279, 4283 and 4289 Don Carlos Dr.

4412 Don Cota Pl.

4001, 4121, 4127, 4201, 4208, 4209, 4323, 4341, 4359 and 4418 Don Diablo Dr.

4223 and 4420 Don Felipe Dr.

4025, 4100 and 4120 Don Ibarra Pl.

4141 Don Jose Dr.

4312, 4319 and 4354 Don Luis Dr.

4206 Don Ortega Pl.

4500 and 4523 Don Rudolfo Pl.

4149, 4315, 4327, 4353, 4427, 4433, 4451, 4495, 4501, 4557 and 4565 Don Tomaso Dr.

4230 and 4233 Don Mariano Dr.

4466, 4488 and 4584 Don Milagro Dr.

4641, 4647, 4731, 4737, 4743, 4749 and 4757 Don Miguel Dr.

4512, 4554 and 4560 Don Valdes Dr.

4400 and 4404 Don Zarembo Dr.

5210 and 5216 El Mirador Dr.

5652, 5658 and 5664 Glenford St.

4074, 4084 and 4123 Mantova Dr.

4130 Punta Alta Dr.

5296 Veronica St.

5409 and 5446 Weatherford Dr.

LOS ANGELES CITY**1978**

5601, 5637, 5667, 5737, 5743, 5751 and 5766 Aladdin St.

5624, 5628, 5738, 5744 and 5752 Brushton St.

6805-9 Brynhurst Ave.

6107 Buckler Ave.

3929, 3934, 3940 and 3952 Carmona Ave.

3933, 3936, 3940, 3947, 3948, 3957, 3958, 3969, 4035, 4055, 4061, 4073, 4139, 4207, 4208, 4215, 4216, 4224, 4233, 4247 and 4251 Cloverdale Ave.

4219 and 4227 Don Alanis Pl.

4213 and 4231 Don Alegre Pl.

4218 Don Arellanes Dr.

4501 Don Arturo Pl.

4223, 4283 and 4295 Don Carlos Dr.

4412 and 4413 Don Cota Pl.
4260 and 4261 Hillcrest Dr.
4046 Mantova Dr.
4216 McClung Dr.
4585 Orchid Dr.
3432 and 3741 Potomac Dr.
4000, 4006 and 4047 Punta Alta Dr.
5163, 5169, 5220, 5264 and 5346 Sanchez Dr.
5358 and 5390 Stillwater Dr.
4216 and 4236 Terraza Dr.
5128, 5146, 5176, 5200, 5231, 5251, 5255, 5260, 5261, 5267, 5272, 5277, 5287 and 5296 Veronica St.
5256, 5369, 5414, 5417, 5434, 5452 and 5460 Weatherford Dr.
4140 and 4212 W. 59th Pl.
4116 W. 62nd St.

LOS ANGELES CITY

1980

5743 and 5766 Aladdin St.
3929 Carmona Ave.
4067, 4171 and 4201 Cloverdale Ave.
4141, 4215, 4224, 4227, 4228, 4229, 4341 and 4523 Don Diablo Dr.
4516 Don Felipe Dr.
4114 Don Ibarra Pl.
4236 Don Jose Dr.
4046 Don Luis Dr.
4517 Don Miguel Dr.
4511, 4557 and 4561 Don Milagro Dr.
4765 and 4772 Don Porfirio Pl.
4429 Don Ricardo Dr.
3815, 4161-67, 4239, 4353, 4421, 4427, 4501 and 4490 Don Tomaso Dr.
4536 Don Valdes Dr.
4608 Don Zarembo Dr.

5606, 5614, 5628, 5634 and 5720 Glenford St.
4014, 4116, 4200, 4215, 4309, 4315, 4323, 4329, 4359 and 4418 Don Diablo Dr.
4511 and 4523 Don Diego Dr.
3906, 4121, 4124, 4127, 4133, 4142, 4200, 4412, 4427, 4433, 4444, 4526 and 4530 Don Felipe Dr.
4019, 4040, 4100, 4108, 4114, 4115 and 4120 Don Ibarra Pl.
4154, 4160, 4236 and 4267 Don Jose Dr.
4611 Don Lorenzo Dr.
4140, 4278, 4306, 4312, 4318, 4324, 4348 and 4354 Don Luis Dr.
4241, 4275 and 4281 Don Mariano Dr.
4411, 4419, 4425, 4470, 4501, 4520, 4531, 4539, 4643, 4647, 4701, 4731, 4736, and 4773 Don Miguel Dr.
4466, 4472, 4494, 4500, 4529, 4535, 4547, 4552 and 4576 Don Milagro Dr.
4749 and 4765 Don Porfirio Pl.
4543 Don Quixote Dr.
4516, 4500, 4523, 4531, 4554, 4557 and 4563 Don Rudolfo Pl.
4101, 4115, 4121, 4127, 4215, 4241, 4245, 4253, 4327, 4301, 4315, 4341, 4353, 4421, 4427, 4451, 4459, 4465, 4509, 4549 and 7427 Don Tomaso Dr.
4506 and 4530 Don Valdes Dr.
4400 and 4616 Don Zarembo Dr.
5200, 5201, 5205, 5222, 5251 and 5269 El Mirador Dr.
5600, 5060, 5628, 5634, 5640, 5720 and 5727 Glenford St.
3009, 3025-27, 4160, 4209 and 4217 Hillcrest Dr.
4123 Mantova Dr.
4035, 4132 and 4138 Punta Alta Dr.
4236 Terraza Dr.
5122, 5128 and 5273 Veronica St.
5460 Weatherford Dr.

LOS ANGELES COUNTY

1969

Not compiled

LOS ANGELES COUNTY

1978

4070 W. Athenian Way
4036 W. Fairway Blvd.
5212 and 5338 W. Garth Ave.
4029 W. Kenway Ave.
5439 and 5447 S. La Cienega Blvd.
4361 W. Mt. Vernon Dr.
3622 W. Northland Dr.
5146 W. Onacrest Dr.
6605 S. Sherbourne Dr.

LOS ANGELES COUNTY

1980

5907 S. Condon Ave.
5724 Deane Ave.
5222 S. Garth Ave.
4700 and 4801 Keniston Ave.
4021 Kenway Ave.
5445 S. La Cienega Blvd.
4214 Mt. Vernon Dr.
3730 and 3852 Olympiad Dr.
4530 Orchid Dr.
5030 Parkglen Ave.
5522 Senford Ave.
4015,* 4025* and 5003 Valley Ridge Ave.
5024 Valleydale Ave.

*Address reported as damaged could not be located.

CULVER CITY (Sub-area I, Plate I)

1978-80

3904 and 3905 Carol Court
3842 and 3846 Crestview Rd.
6207 and 6227 Hetzler Rd.
3856 Howardview Court
9300 and 9530 Jefferson Blvd.
3819, 3823 and 3849 Perham Dr.
3983 and 3955 Shedd Terrace
6011 Wright Terrace
5947, 5949 and 6003 Wrightcrest Dr.

CULVER CITY (Sub-area 4, Plate I)

1978-80

10826, 10828, 10830 and 10834 Bernardo Rd.
10715, 10725, 10730, 10735, 10737, 10745, 10747, 10751 and 10753 Cranks Rd.
5916, 5922 and 5924 Culview St.
10638, 10642, 10646, 10650 and 10656 Drakewood Ave.
10698 Esterina Way
10626 Flaxton St.
5913, 5923, 5925 and 5927 Hill Rd.
10688, 10716 and 10724 Lugo Way
10660 and 10668 Ranch Rd.
5714, 5716, 5718, 5720, 5722, 5724 and 5819 Tellefson Rd.
10601, 10602, 10604, 10607, 10611, 10612, 10616, 10618, 10626, 10627, 10631, 10639, 10641 and 10649 Youngworth Rd.

APPENDIX III

Glossary of Selected Terms Used in this Report

- Alluvium:** (1) Younger alluvium consists of deposits of loose, heterogeneous and incoherent clay, silt, sand, and gravel which accumulates along the bottom of canyons, especially in stream beds and flood plains. Such deposits are derived by outwash of eroded material from hills and mountains, commonly by debris flooding. (2) Older alluvium (or terrace deposits) consists of alluvial deposits no longer part of active stream channels or flood plains. Such deposits may be relatively consolidated, uplifted and tectonically deformed.
- Ancient landslide:** A prehistoric landslide; generally a landslide whose age can be measured in many hundreds or even thousands or tens of thousands of years. Some still-active or potentially active landslides in southern California are known to be older than 10,000 to 20,000 years of age.
- Artificial fill slope:** See *Fill slope*.
- Artificial fill:** A general term for material that is placed on natural or artificially cut ground surfaces by man. Includes compacted and non-compacted and engineered and non-engineered fill. (Also see *Engineered fill*.)
- Batter board:** An informal term for revetment system. See *Revetment system*.
- Bedding plane:** A surface of depositional layering in a stratified sedimentary rock that visibly or invisibly separates successive stratigraphic layers. It is also a surface along which a stratified sedimentary rock, such as platy or clay shale, splits apart.
- Bedrock:** Bedrock is considered to be any naturally occurring earth (rock) material that is firm and hard, such as sandstone and granite. This includes sedimentary deposits that are well-consolidated, indurated or cemented. Common types of bedrock in the study area are sandstone, siltstone, shale and conglomerate.
- Bedrock landslide:** A deep-seated, massive landslide that involves bedrock, in contrast to a surficial landslide (or "slide" or flow) that involves only soil and colluvium that has developed on bedrock. Bedrock landslides have components of translational or rotational movement or combinations thereof. Also see *Rotational slope failure* and *Translational slope failure*.
- Bench (terrace) drain:** A drain generally constructed of concrete that is placed on step-like, slightly off-level benches on slopes to control erosion and stability of the slopes. Such drains collect rain and surplus irrigation water which then is fed into surface or subsurface down-drains. Specifications for construction and interval of placement of benches and down-drains on slopes are provided in local building codes and in the Uniform Building Code.
- Berm:** A relatively narrow, horizontal man-made shelf, ledge, or bench built along an embankment, breaking the continuity of a slope.
- Block glide:** A translational, non-rotational landslide in which the slide mass moves outward and downward along a pre-existing plane of weakness, including bedding planes (especially bedding planes of clay shale), foliation, joints, and faults.
- Buttress fill:** A designed ("engineered") compacted earth fill used for providing lateral support to an unstable rock or soil mass. It is keyed via a trench into bedrock at the base of the slope. Local grading codes define its specifications.
- Clay:** Common clay consists of any very fine-grained rock material that is soft and plastic when wet (including the very fine-grained material of fault gouge and clay shale). In addition, and more scientifically, clay consists of one or more of the clay minerals (kaolinite, montmorillonite and so forth) that commonly form by weathering and alteration of certain rocks (such as beds of tuff in sedimentary rocks); smectite (montmorillonite and beidellite) is especially expansive when wet and therefore is commonly the basis, unless controlled, for the hazards of slope instability and foundation cracking. (Reference: Borchardt, 1977)
- Colluvium:** Heterogeneous and incoherent soil and minor rock material derived from weathering of bedrock that gradually moves down slope principally by the forces of gravity, thickening on the lower parts of slopes and in swales in slopes. Commonly, colluvium contains abundant clay that causes it to expand when wet. (Includes slope wash).
- Compacted fill:** Fill consisting of bedrock and soil material that has been densified by the use of compaction equipment, such as sheepfoot rollers.
- Cut slope:** A slope that is artificially cut by man generally so that bedrock is exposed.
- Daylighting:** An informal term used commonly by engineering geologists which means that the angle of the dip of strata (or soil developed on bedrock) exposed in a natural or artificial cut is less than the angle of the slope. Thus the strata or soil are particularly vulnerable to sliding. In the Baldwin Hills, "daylighting" occurs in cut slopes and at tops of scars of shallow landslides where soil developed on bedrock is exposed ("daylighted"). See Figure 14, item 5 for an illustration of "daylighting."
- Debris fence:** A sturdy fence generally made of pipes and wire, commonly constructed in series in ravines or swales, to block or impede the flow of debris.
- Debris flow:** A type of landslide that consists of a watery mixture of rock material, soil, colluvium and vegetation derived from moderate to steep slopes that may move down slope very suddenly and very swiftly and therefore may cause serious damage and serious injury or death to persons in its path. Debris flows generally occur during prolonged intense rain when vulnerable sites become saturated with water. Mudflow (mud flow) is a debris flow that consists nearly entirely of mud.

*Definitions partly from Gary and others (editors, 1972), Hutchinson (1968), International Conference of Building Officials (1976 edition), Los Angeles City (1977), J.T. McGill, in U.S. Corps of Engineers (1976), Sharpe (1938), and D.J. Varnes, in Schuster and Krizek, editors (1978).

Deflection wall: Sturdy wall commonly in V-shaped plan, with "V" up drainage, to deflect flow of debris around a property.

Engineered fill: Artificial fill that is compacted under engineering supervision to a specified density which is confirmed by testing.

Engineering geologist: (Certified Engineering Geologist). A geologist capable of practicing the elements of geology used in the construction of civil works or some aspect of planning, design and development involving construction of civil works. In California, the law requires that such persons who independently practice engineering geology be registered and certified by the state.

Erosion: The incremental removal of soil and rock material from slopes by the direct force of rain or by running water or even wind or moving ice.

Expansive soil: Clay-rich soil that expands when wet to such an extent that it may crack overlying foundation slabs and walls. It can be removed before construction or treated by a pre-construction wetting process. Also see *Clay*.

Fill slope: A slope on artificial fill. Such a slope on compacted ("engineered") fill is designed to and constructed to specifications set forth in the building code at the time the site was graded.

Foot: Lower part of a landslide or slope. See also *Toe*.

Graben: Down-dropped block within a fault zone.

Graded slope: A slope developed by grading. Graded slopes are now required normally by building codes to have no more than one unit of vertical rise for every two units of horizontal reach, or a slope angle of about 26.5°; these are known as 2:1 or 2 to 1 slopes. (Steeper slopes may be permitted if they can be shown to be stable.) Graded slopes in the Baldwin Hills commonly reach angles of 33.5° (1 1/2:1) and even 45° (1:1) or steeper; these slopes were graded before stringent grading codes were adopted.

Grading: The process by which natural terrain is modified, especially using cut and fill, for development of small or large residential tracts or for individually sited buildings or for other engineering structures.

Grading code: That part of the local city or county building code that establishes the law for grading terrain for development and construction.

Gully: A shallow to deeply incised natural trench in a slope that is caused by the force of running water.

Headwall scarp: Bare wall left at head (or top) of a landslide after the slide mass moves.

Holocene: The epoch of the Quaternary period of geologic time which dates back about 10,000 years ago from the present.

Landslide: Downhill movement of a discrete portion of the earth's surface caused by gravity. The general occurrence of landslides is related to climate; individually, they are activated or reactivated by prolonged rainfall, but they also can be triggered by shaking caused by earthquakes. Landslides may

range in surface area from approximately a few square yards to more than a square mile. The material that slides may move as a unit or it may completely disorder or even disaggregate or liquefy; if it disaggregates and is saturated with water it may flow rapidly or ooze slowly. In contrast, large bedrock landslides may move almost imperceptibly slowly. For this study, "soil creep" and such phenomena as a single boulder or several boulders breaking loose and rolling downslope do not constitute landslides.

Liquefaction: The temporary transformation of a cohesionless material, such as unconsolidated or poorly consolidated sandy silt or silty sand, into a fluid mass. The transformation is caused by a sudden, large decrease in shearing strength. This may occur in parts of the study area underlain by alluvium or colluvium during strong ground shaking caused by large earthquakes where the water table is relatively close to the ground surface. If the ground surface slopes, even very gently, the deposits that liquefy may move (laterally spread) a short distance.

Liquid limit: The maximum limit of water content of a material in a plastic state; addition of more liquid causes the plastic material to liquefy. Liquid limit is one of the Atterberg limits.

Mudflow (mud flow): See *Debris flow*.

Mudslide (mud slide): See *Surficial landslide*.

Natural slope: The slope of natural terrain that has not been modified by man.

Non-engineered fill: Artificial fill that is loose and uncompacted or has been compacted without engineering supervision and, therefore, either lacks the quality of engineered fill or has not been tested for this quality.

Pad (building pad): A near-level area graded for construction of a house or other building.

Pleistocene: The epoch of the Quaternary period of geologic time that dates back from the beginning of Holocene time (about 10,000 years ago) to the end of Pliocene time (about 2 million years ago).

Pliocene: The epoch of the Tertiary period of geologic time which dates back from the beginning of Pleistocene time (2 million years ago) to the end of the Miocene epoch (5 to 7 million years ago).

Reactivated landslide: An ancient or historical slump or glide that exhibits renewed movement.

Relict paleosol: A soil that developed in the past (commonly the ancient past) which survives as remnants in places where it could not form in today's climatic environment.

Revetment system: A terracing system of boards supported by posts that are placed or driven vertically into a slope to retain surface materials and to control drainage.

Rills: Closely spaced, generally shallow indentations down a slope which are caused by erosion resulting from fast flowing water.

Rodent control: Elimination of the activity of gophers and other digging and burrowing animals that weakens slope stability and whose holes and tunnels allow access of water which stimulates the deterioration of slopes.

Rotational slope failure: Type of slope failure in which the movement of a slide mass occurs along a surface that is concave upward, thus having upward movement that is rotary and yields a slump. This failure contrasts with *Translational slope failure*.

Scarp: A steep linear escarpment or linear series of cliffs produced by faulting or erosion.

Shear key: An engineered buttress fill with the shape of an inverted "V" (in profile) that is constructed downward to below the slide plane of a landslide to buttress the landslide mass and prevent its movement.

"Skin" slide: A colloquial term for a very thin surficial debris slide or soil slip.

Slide plane: The surface along which a landslide mass moves.

Slope angle: The vertical angle measured between the surface of a slope and a horizontal line directly above it. Also see *Graded slope*.

Slope failure: A common term used for the occurrence of landslides (such as surficial debris flows and slides including soil slips) and severe erosion in slopes.

Sloughing: Very surficial crumbling and sliding from the surface of a slope that is usually very steep; hence, generally, a very minor slope failure.

Slough wall: A wall with sufficient freeboard (height) above the slope to stop or divert the down-slope flow of water and debris when a slope fails.

Slump (rotational landslide): A landslide characterized by shearing and rotational movement of a generally independent

mass of bedrock or fill material along a curved slip surface that is concave upward. The resulting slump mass (or block) therefore rotates upward at its toe and downward at its head.

Soil: For this report soil consists of the zone of weathering that occurs at the ground surface (the term is defined more precisely by soil scientists). Soil is also defined for some engineering purposes as any naturally occurring earth material that is unconsolidated and incoherent, such as alluvium.

Soil creep: Imperceptible down-slope movement of soil and other surficial materials. Contrasts with *Surficial landslide* in which movement of surficial materials is very perceptible.

Soil "pop-out": An informal term for a small, shallow rotational failure.

Soil slip: Surficial slide and/or flow derived from very thin soil and colluvium.

Surficial landslide (or slide): Slow to rapid down-slope movement of surface mantle materials. These materials consist of predominantly unconsolidated and incoherent earth, soil, debris and vegetation that commonly are developed on or overlie bedrock and which may develop on compacted fills. If the materials are saturated with water during heavy rains, and the slope is sufficiently steep and lengthy, a slide may evolve into a flow. See also *Soil creep*.

Toe: The part of a landslide mass or slope that is farthest down-slope. See also *Foot*.

Translational slope failure: Type of failure in which movement occurs along a surface that is essentially planar, and commonly essentially parallel to the ground surface. The surface of movement (or glide) is commonly a bedding plane. Contrasts with *Rotational failure*.

Uniform Building Code: The nationwide code in the form of a book that is used by many local governments to regulate construction. Chapters 29 and 70 refer to grading and other geological aspects of construction. See "References Cited."

APPENDIX IV

Aerial Photography Utilized in Baldwin Hills Slope Stability Study

DATE	SCALE	FLIGHT	FRAMES
1927	1" = 1500'	Fairchild*-Flight C-113	Frames 80-85, 127-134, 168-174
1928	1" = 1500'	Fairchild*-Flight C-300	Frames K50-K55, K78, K79
June 9, 1936	1" = 600'	Fairchild*-Flight 4053	Frames 1 to 34
1940	1" = 2000'	Fairchild*-Flight 6630	Frame 8
December 21, 1941	1" = 2000'	Fairchild*-Flight 7595	Frames 6, 7, 8
1951	1" = 2000'	Fairchild*-Flight 16580	Frames 4 to 6, 13 to 16
1952	1" = 2000'	Fairchild*-Flight 17979	Frames 18-18 to 18-21
1953	Various	Fairchild*-Flight 19375	Frames 3-12 to 3-14; 4-21 to 4-28; 4-25 to 4-49
February 6, 1956	1" = 800'	Fairchild*-Flight 22412	Frames 13 to 18, 26 to 28
July & August 1956	1" = 1200'	Fairchild*-Flight 22555	Frames 17-23, 17-24, 18-23, 18-24
January 3, 1964	1" = 200'	Fairchild-Flight 24697	Photo mosaic index only
1978	1" = 2000'	L.A. City	Sheets 50NE and 51NW (Enlarged to 1" = 400')
August 22, 1979	1" = 2000'	Teledyne Geotronics Flight 3800-001	Frames 14-27 & 14-25 (Enlarged to 1" = 400')
April 14, 1980	1" = 500'		U.S. Army, Corps of Eng.
April 14, 1980	1" = 1000'	U.S. Army, Corps of Eng.	
June, 1976	1" = 200'	Orthophoto Map of Culver City	
April, 1980	1" = 100'	Orthophoto Map of Culver City	

*Available for reference at Whittier College; prints of many flights available from Teledyne Geotronics.

APPENDIX V

Credits for Tables, Figures, Photos and Plate I

TABLES

E.Y. Hsu - 1
 E.Y. Hsu, S.S. Tan and J.A. Treiman - 2
 J.A. Treiman - 3a-b
 E.Y. Hsu and S.S. Tan - 3c-d
 F.H. Weber, Jr. - 4

FIGURES

F.H. Weber, Jr. - 1-5, 7a-b, 10, 12, and 19.
 E.Y. Hsu - 6a-c.
 V.A. Protasov (Compiler) - 11.
 E.Y. Hsu and S.S. Tan - 13-18.
 R.B. Saul - 8-9.

PHOTOS

Spence Collection, Courtesy of Department of Geography, University of California, Los Angeles - 1-2, 4, 7, 10-11, and 13.
 Fairchild Collection, Courtesy of Whittier College - 3.
 History Division, Courtesy of Los Angeles County Museum of Natural History - 8.
 R.B. Saul - 5-6, 9, 29, 30-33, 35-36, and 38-41.
 R. Taber: Courtesy of A.G. Barrows - 12.
 John Shadle, Courtesy of Los Angeles City Department of Building and Safety - 16-17, 19-21, 24-25, and 27.
 F.H. Weber, Jr. - 18, 26, and 28.
 S.S. Tan - 22-23.
 J.A. Treiman - 14-15, 34, and 42-43.
 County of Los Angeles; Courtesy of P.A. Amimoto - 37.

PLATE 1 - Staff (in alphabetical order): E.Y. Hsu, R.B. Saul, S.S. Tan, J.A. Treiman, and F.H. Weber, Jr. Graphics by V.A. Protasov.

APPENDIX VI

Geologic Hazard Abatement Districts

In 1979, section 26500 was added to the Public Resources Code of the State of California. This section provides a method for establishing "Geologic Hazard Abatement Districts." It is a result of Senate Bill 1195, introduced by Senator Robert G. Beverly. Action to form such districts can be initiated (sec. 26550.5) by a "petition signed by not less than 10% of the real property owners to be included in such a district," or it can be initiated by the local legislative body (City Council, Board of Supervisors) having jurisdiction over the area. If more than one body is involved (26551), the body with the greatest assessed valuation to be included in the district assumes jurisdiction.

The next step in the process involves the legislative body with jurisdiction making a resolution to initiate proceedings to establish the district (26558). The resolution includes a statement that the legislative body has received a "plan of control" (26509) which describes the geologic hazard in detail and has "—a plan for the prevention, mitigation, abatement or control thereof." The plan is prepared by an engineering geologist certificated by the State, or a firm of engineering geologists. The resolution also sets a public hearing. "If it appears at the public hearing that owners of more than 50 percent of the assessed valuation of the proposed district object to the formation thereof, the legislative body shall thereupon close the hearing and direct that proceedings for the formation of a district be abandoned" (26566).

If 50% do not object, and the plan of control is accepted, the hearing proceeds. Either at the close of the hearing or within 60

days thereafter (26567), the legislative body appoints five owners of real property in the district as a board of directors with terms not to exceed 4 years, or the body can appoint itself as the board with a term not to exceed 4 years. Thereafter the board is elected by the district.

The district established is an agency of the state and is not a local agency (26570). "A district is comprised of an area specially benefited by and subject to special assessment to pay the cost of an improvement" (26571). "The lands included within a district may be contiguous or non-contiguous" (26530). "Lands may be privately or publicly owned (26532)." "All lands within the district shall be specially benefited by construction proposed in a plan of control approved by the legislative body" (26534). The district may sue and be sued and it may make, amend and repeal bylaws (26574). It may "acquire real property of any interest therein by eminent domain" (26576).

The district may enter into contracts and agreements with the United States, State, or local units of government, private organizations or persons (26579). It may use one of three prior State Acts to pay costs of an improvement pursuant to this Division (26587). It may accept financial or other assistance from any public or private source (26591). "The board of directors may negotiate improvement contracts or may award such contracts by competitive bidding pursuant to procedures approved by the board of directors" (26600).

APPENDIX VII

**Participation in this Project by Division of Mines
and Geology and Department of Conservation
Staff, and Curriculum Vitae for Principal Investiga-
tors**

The study was made in the Los Angeles District of the California Division of Mines and Geology. Field mapping of slope failures and closely related geologic features in residential areas of the Baldwin Hills began in mid-March 1980, and was done mostly by S.S. Tan and J.A. Treiman. E.Y. Hsu joined the aforementioned investigators on July 1 in preparation of descriptions and discussions of slope failures and accompanying maps for the initial product of the study, a report open-filed in November 1980 (California Division of Mines and Geology staff, 1980). Hsu also prepared the section on grading codes, and worked with Tan, Treiman, and F.H. Weber, Jr. on the section on general evaluation of slope failures and recommendations for stabilization of slopes.

The geologic portion of Plate 1 was compiled principally by R.B. Saul in association with the aforementioned investigators. Saul also investigated slope failures and geologic features of the Inglewood oil field area of the hills, with the latter aspect of this work leading to modification of the geological portion of the compiled map. Weber was project leader, and prepared most of the introductory sections to the report and acted as editor. Details on authorship of various sections of the report is provided in the section on "Contents."

Modification of the Open-File Report was done during the period December 1980 to April 1981, with geological work by Hsu, Saul, Treiman, and Weber. Modification included consolidation of the black and white plates of the Open-File Report into the one colored plate for this report (see also Appendix VIII).

Additional technical input was provided as follows: Glenn Borchardt, of the San Francisco District office of the Division of Mines and Geology, made a field analysis of soil relationships in the study area. Allan G. Barrows, of the Los Angeles District office, provided materials from his previous study of the Newport-Inglewood structural zone (Barrows, 1974), discussed various aspects of the study area with Saul and Weber and reviewed most of the section entitled "Factors that Relate to Slope Instability and Failure in the Baldwin Hills."

Clerical functions relating to the project were performed by Wilma L. Ashby, Bernice H. Browne, V. Ann Devney, Venice Huffman, Esther E. NeSmith, and Sue E. Torres. Word processing of the report was done chiefly by Huffman, with assistance from Devney and NeSmith. Public relations work for the project was done by Huffman and Torres. Cartographic services were provided by Elizabeth M. Lindgren, Victor A. Protasov, Martha L. Oman, and Robin I. Weber. Protasov drafted Plate 1 of the present report. Camera-ready layout and design was prepared by Edward L. Foster. The report was published under the supervision of Robert Streitz and R.M. Smith.

The principal administrator for the project was T.E. Gay, Jr., Chief Deputy State Geologist. Administrative support in the Los Angeles District was provided by C.H. Gray, Jr., District Geologist, T.P. Anderson, formerly Assistant District Geologist, and A.G. Barrows, Assistant District Geologist.

The present version of the report has been reviewed administratively by Brian H. Sway, Deputy Director of the Department of Conservation. The open file report was reviewed by Priscilla A. Grew, formerly Director of the Department of Conservation, Michael Gersick, formerly Deputy Director of the Department, and Thomas E. Gay, Jr., Chief Deputy State Geologist. Comprehensive editing of the final version of the report by Jon C. Lloyd led to considerable strengthening of its organization.

Curriculum Vitae

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APPENDIX VIII

Preparation of Plate I

The areal geology portion of Plate I was compiled principally by R.B. Saul from an informally published, open-file geologic map of the Baldwin Hills by R.O. Castle of the U.S. Geological Survey (Castle, 1960a). This map is dated 1960. Additional data pertaining to the alluvial deposits and artificial fill north and west of the hills were taken from a map of the Beverly Hills and Venice quadrangles by Castle, also dated 1960 (Castle, 1960b). Still additional data were taken from reports by Castle and Yerkes (1976), California Department of Water Resources (1964) and Engineering Geology Consultants, Inc. (1975). Data from Castle's Baldwin Hills maps were enlarged from 1 inch equals 1,000 feet to 1 inch equals 400 feet for compilation onto Plate I of this report. This expedient enlargement for the compilation caused certain errors in accuracy to become inherent in the compiled map. Thus the map must be used very carefully in this regard. Detailed site maps should be prepared prior to undertaking any engineering project in the hills.

Some modification of source material for the compilation of the areal geology of Plate I resulted from the detailed mapping of slope damage in residential areas by J.A. Treiman, S.S. Tan and E.Y. Hsu. Boundaries of fills in steep-sloped residential areas were compiled onto Plate I principally from the original tract development maps on file with Los Angeles City and

County Departments of Building and Safety and the City of Culver City. In addition, mapping by Saul and Hsu in the Inglewood oil field area led to modification of contacts among Pleistocene units. Pre-development landslides outlined on Plate I are based principally on aerial photograph interpretation by Treiman and Tan. Several ancient landslides were mapped by Saul in Sub-area 5. Additional, possible landslides are shown in Figures 7a and 7b. Contacts among alluvial and colluvial units also have been modified somewhat from the mapping of Castle (1960a-b). The mapping for this study of former marshy ground north of the hills was based on interpretation of early aerial photographs and topographic maps (Figure 10).

The location and number of west-northwesterly trending faults along the north slope of the Baldwin Hills and to the north of the hills on Plate I are slightly different than on Castle's maps. A west-northwest trending fault mapped by Castle (1960a) along the mid part of the north flank of the hills, similar to one mapped by Poland and others (1959, Plate 2), is shifted to the north on Plate I for this study and is called the Baldwin fault. The name "Baldwin" for a fault along the north flank of the hills was first used by Chevron U.S.A., Inc. (R.C. Erickson, Chevron U.S.A., Inc. San Francisco, verbal communication, 1981).

118° 22' 30"



EXPLANATION
Rock Units*

Qf

Artificial Fill

Undifferentiated compacted and uncompacted fill

Qco Qfp Qfpm

Younger Colluvium and Alluvium

Qco - Undivided colluvium and alluvium within the Baldwin Hills and around their periphery, including slope wash and alluvial fan deposits. Deposits are unconsolidated, generally fine-grained and consist of silt, sand and minor gravel, slope wash locally is clay-rich.

Qfp - Floodplain and stream channel deposits of Ballona Creek, unconsolidated sand, gravel and silt.

Qfpm - Former marshy area in Ballona Creek floodplain, as identified on pre-development aerial photographs and maps.

Qpu

Older Alluvium

Deposits of Ballona Creek floodplain that have been slightly uplifted tectonically.

Qls

Pre-development Landslides

Mostly ancient, massive, deep-seated landslides derived from bedrock (Qb, Qc, Qi), also, shallower landslides, mainly derived from thick deposits of soil and colluvium (red locality 18, for example).

Qf

Fox Hills Relict Paleosol

Reddish brown, well-cemented and resistant (paleosol) developed on erosional surface underlain by Qb, which range from silty sand to sandy silt.

Qb

Baldwin Hills Sandy Gravel

Nonmarine deposits that range from gravely sand to sandy gravel and are poorly sorted and crudely stratified, and are interlayered with lenses and beds of clayey silt and clay. In part, these deposits grade northerly in the west part of the area to well-bedded clayey silt and minor sand and gravel. Coarse clasts typically are angular to subangular.

Qc

Culver Sand

Marine deposits that range from moderately sorted and crudely stratified sand and gravel with large-scale cross bedding to well-sorted and well-laminated sand with minor gravel and silt. Coarse clasts typically are well rounded to subrounded.

Qi

Inglewood Formation

Marine deposits that consist mainly of well-bedded substone with inter-layered beds of very fine-grained sandstone. Calcareous and limonitic concretions are locally abundant.

*Note: The informal names "Culver sand", "Baldwin Hills sandy gravel" and "Fox Hills relict paleosol" were adopted by the California Division of Mines and Geology for use in this study.

FAULTS AND CONTACTS
BETWEEN MAP UNITS

Faults

75 0 0

Solid line where relatively accurately located, dashed line where approximately located, dotted line where concealed by alluvial and colluvial deposits, queried where inferred. Arrow and number show direction and angle of dip, respectively. U, apparent upthrown side; D, apparent downthrown side. (Mainly as compiled from Castle, 1964a, with modifications and additions for this study.)

U

Indefinite or inferred faults (as compiled from Castle, 1964a). Dotted and queried where apparently concealed beneath alluvial or colluvial deposits. U, apparent upthrown side; D, apparent downthrown side.

Contacts

Solid line where relatively accurately located and where approximate, dotted where concealed.

Additional Symbols

1-2

Strike and dip of sedimentary beds

SYMBOLS AND LINES IN RED RELATE TO
SLOPE DAMAGE AND REPAIR

EXPLANATION

ABSTRACT

SER (72)

Areas of slope damage are outlined and symbolized as follows: S, damaged by surficial landsliding; E, damaged by erosion; R, indicates that the slope has been repaired, as of 1980. Locality shown is described in Table 3C and discussed in the text under slope segment 3N. See additional sub-headings for further explanation.

TYPES OF SLOPE FAILURE

Erosional rilling and gulying of slopes

E

General areas of slope damage caused by erosion, boundaries are approximate at some localities. The letter "E" without boundaries symbolizes an area of erosion too small to be delineated.

Individual erosion gullies

Surficial landslides

S

General areas of slope damage caused by surficial debris slides (including soil slips), debris flows, and shallow slumps, which usually are less than 10 feet deep, boundaries are approximate at some localities. The letter "S" without boundaries symbolizes the general location of a debris flow, surficial slide or shallow slump that is too small to be delineated.

Shallow slumps and slides (including soil slips). An area delineated and generally includes more than one failure; the general direction of failures is shown by a straight arrow, an arrow without boundaries symbolizes a shallow slump or soil slip too small to be delineated. Hachures symbolize headwall ("pullaway") scarp at top of feature.

Debris flows. An area delineated may include more than one flow; boundaries are usually approximate; solid wiggly arrows show direction of failures that occurred in 1978 or 1980; a wiggly arrow without boundaries symbolizes a debris flow too small to be delineated, broken wiggly arrows designate the paths of flows that occurred before 1969, as interpreted from pre-1969 aerial photographs. Hachures symbolize headwall ("pullaway") scarp at top of feature. [Data for aerial photographs of various dates and scales that were utilized for this study are tabulated in Appendix IV.]

Debris deposited by slumps or flows

General locality symbolizing incipient slumps that probably will be reactivated during the next period of severe rains similar to those of 1978.

Deep-seated Landslides

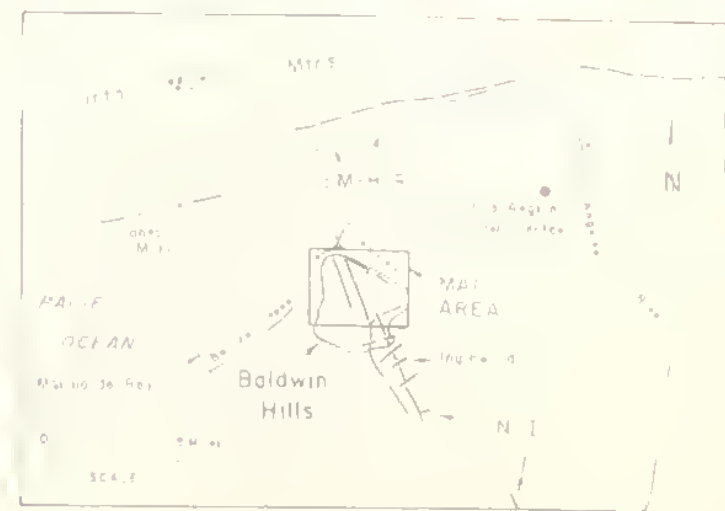
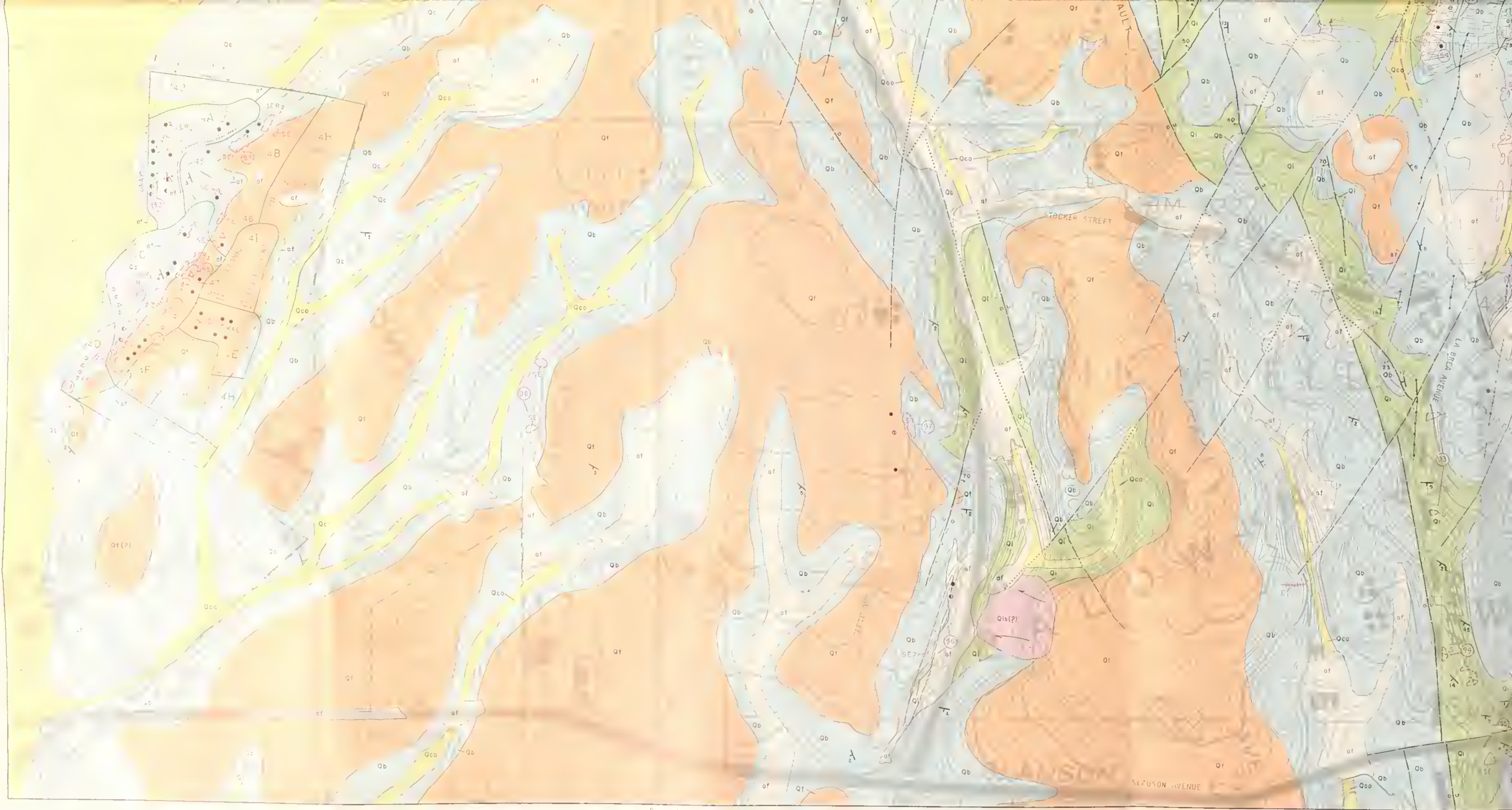
Massive, deep slumps that occurred in Sub-areas 1 and 2 in 1978 and 1980. Hachures symbolize headwall ("pullaway") scarp at top of landslide.

Miscellaneous map symbols related
to slope failure and other ground rupture.

Scarps that developed in 1978 and 1980 at the tops of areas of erosion or shallow slumping.

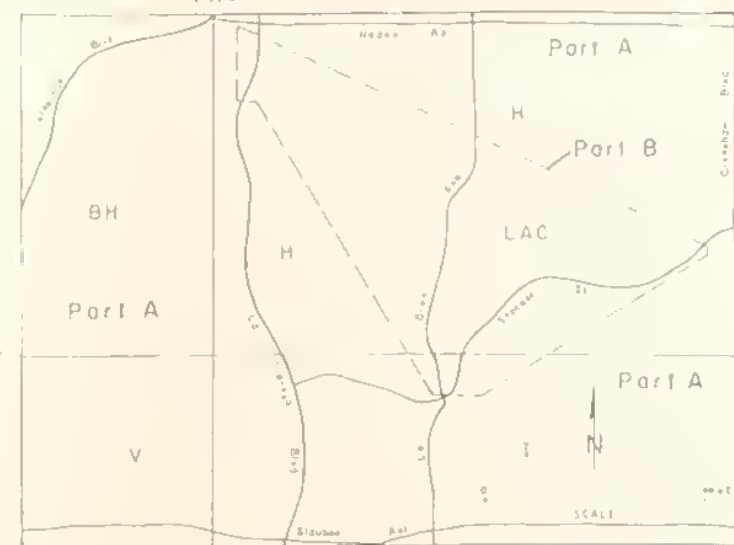
Scarps that developed before 1969 at the tops of areas of erosion or shallow slumping, as interpreted from pre-1969 aerial photographs.

Occurrence of erosion or surficial landsliding is noted for properties listed in damage reports prepared by City and County of Los Angeles following 1978 rains, but feature could not be identified during 1980 field investigations.



LOCATION MAP.

Symbols N-I, Newport-Inglewood fault zone, SM-H-R, Santa Monica-Hollywood-Raymond fault zone

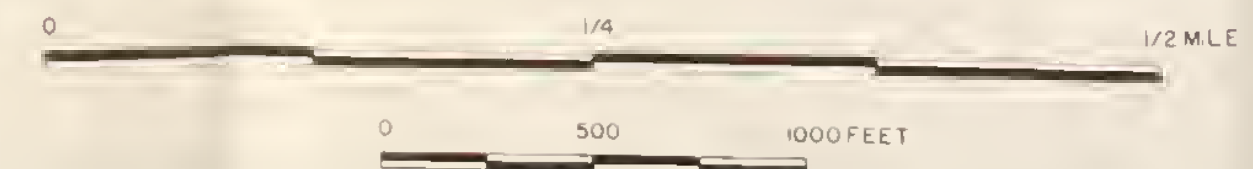


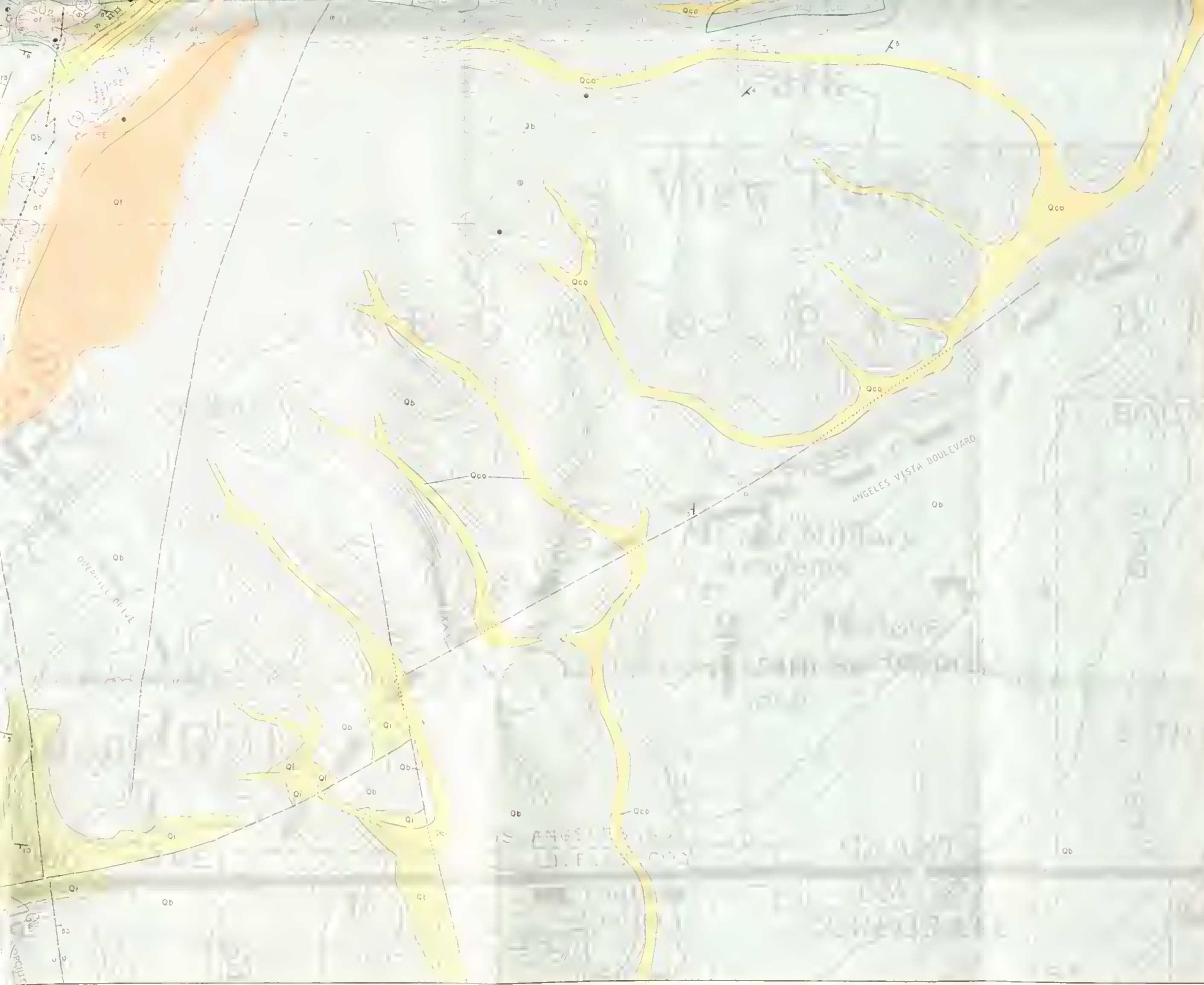
Base map, Part A (as shown on accompanying index map) was prepared by enlarging a mosaic of adjoining parts of the following U.S. Geological Survey 7 1/2-minute quadrangles, editions of 1972: Beverly Hills (BH, contour interval 30 feet), Hollywood (H, contour interval 20 feet), Inglewood (I, contour interval 5 feet), and Venice (V, contour interval 10 feet). Part B is a mosaic of maps of the Baldwin Hills-Playa del Rey series of the Los Angeles City Department of Building and Safety (contour interval 5 feet).

GEOLOGY OF THE NORTHERN BALDWIN HILLS SHOWING SLOPE FAILURES THAT OCCURRED IN 1978 AND OTHER YEARS, AND ADDITIONAL FEATURES RELATING TO THE STABILIZATION OF SLOPES

By California Division of
Mines and Geology Staff
1981

SCALE 1:4,800; 1 inch = 400 feet

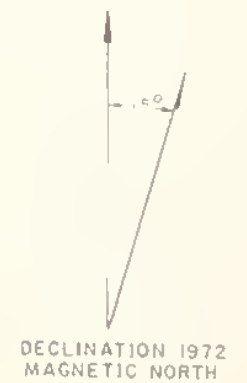




This project was mandated by Assembly Bill 1571, introduced in the State Assembly by Assemblywoman Gwen Moore on March 14, 1979, and signed into law by Governor Edmund G. Brown, Jr., on March 11, 1980.

Williams & Heintz Map Corporation, Capitola, California 95010

Graphics by Victor A. Protosov



Strike and dip of sedimentary beds

Horizontal bedding

Earth crack (from Castle, 1960a, Castle and Yerkes, 1976; and California Department of Water Resources, 1964)

Arrows show direction of landsliding where appropriate; landslides tentatively identified are queried.

LOCALITIES FOR SOIL AND ROCK SAMPLES

EXPLANATION

Localities from which rock or soil samples were taken by consultants for analysis of engineering properties. Samples are described in Table 2. Data are from consulting reports on file with Los Angeles City, Los Angeles County and Culver City.

Cracks along which pavement has settled or has been uplifted; half is on relatively down-dropped side.

Bench drains or tops of man-made slopes, plotted locally where significant to discussions of localities in text.

REPAIR OF SLOPES

Slopes regraded and restored with engineered fill or soil cement fill.

Slopes stabilized with landscape revegetation structures.

Slope repair includes construction of concrete block walls.

NUMBERING OF LOCALITIES

Localities are numbered consecutively from 1 to 98, starting in Sub-area 1 and stopping in Sub-area 6. See table under "Sub-areas studied" in adjacent column for further explanation.

A single leader line points to a feature that is described in the text. The example shown points to an area of surficial landsliding.

Multiple leader lines point to and include two or more slope features described in text. The example shown includes 5 small areas of slope failure.

Locality number without a leader line or lines is plotted within the general, non-delineated area of a feature described in the text and Tables 3a-d.

INDEX MAP SHOWING SUB-AREAS STUDIED

SCALE

0 1+1E

SUB-AREA

GOVERNMENTAL JURISDICTION

LAND USE

TYPE OF SLOPE FAILURE IN 1979 AND 1980

SLOPE SEGMENTS

LOCALITIES

INVESTIGATORS

EXPLANATION

1	Culver City and Los Angeles City and County	Residential and commercial	Surficial slides and flows; one backrock landslide fill settlement	1A-H	1-8	J.A. Treiman	1969
2	Los Angeles City	Single family residential	Widespread surficial slides; debris flows and erosion in cut, fill and natural slopes; asphalt fill settlement	2A-V	9-61	J.A. Treiman	1978
3	Nearly all Los Angeles City; Los Angeles County south of Stocker St. only	Single family residential except apartments mostly along Don Fernando Dr. and Don Ricardo Dr.	Widespread surficial slides; debris flows and erosion mostly in cut and fill slopes	3A-X	62-81	E.Y. Hsu and S.S. Tan	1980
4	Culver City	Single family residential	Numerous surficial slides and debris flows in cut and natural slopes	4A-E	82-89	E.Y. Hsu and S.S. Tan	1969 and 1978
5	Los Angeles County	Mostly commercial, principally an oil field	Erosion principally in dirt (blue shale) debris flow; onto La Cumbre Blvd.	None	90-92	R.B. Saul and F.H. Weber, Jr.	1978 and 1980
6	Los Angeles County	Mostly single family residential	Surficial slides and debris flows at several localities	None	93-98	E.Y. Hsu, S.S. Tan, and F.H. Weber, Jr.	1969 and 1980

* Individual sub-areas investigated are shown on accompanying index map.
** Slope segments and localities are described in Tables 3a-d and in text under Sub-areas 1 to 6.
4. Localities 90-98 are described in the text under Sub-areas 5 and 6.

The geologic portion of this map was compiled by R.B. Saul with assistance from E.Y. Hsu and F.H. Weber, Jr. Lithologic and fault data are principally from a geologic map of the Baldwin Hills by R.O. Castle (1960a), which has a scale of 1 inch equals 1,000 feet. Castle's map was enlarged 2.5 times and compiled onto the modern topographic base map used for this plate. Additional geologic data are mostly from field and other investigative work and aerial photograph interpretation for this study by J.A. Treiman and S.S. Tan, and Saul, Hsu and Weber; these data especially include depiction of artificial fill (af) (sub-areas 1, 2, 3, and 4) and pre-development landslides (Qls) (all sub-areas). Additional information relating to the compilation of the geologic portion of the map is provided in Appendix VIII of the report.

Symbols show properties damaged by the effects of rainfall in 1969 (Los Angeles City portion of Sub-areas 2 and 3 only), 1978 and 1980. Symbols are placed on outline of principal building of properties damaged in Sub-areas 2 and 3 and partly in Sub-area 6 and on approximate site of buildings in other areas. Data are partly from lists of damaged properties prepared by City and County of Los Angeles and by Culver City and partly from field observations during this study. Addresses of damaged properties are listed in Appendix II of the report.

LETTERING OF SLOPE SEGMENTS

2H

Slope segments (outlined in green) are lettered separately within Sub-areas 1 to 4 and discussed in the section of the text covering the pertinent area. Example shown is slope segment H in Sub-area 2.

3N2

Subscript numbers are used to subdivide slope segments for description and discussion in the text. Example shown is Subsegment 2 of Slope segment N in Sub-area 3.

TABLE 1a. DESCRIPTIONS OF SLOPE FAILURES IN SUB-AREA 1, THE NORTHWEST PART OF THE BALDWIN HILLS, By J.A. Treiman

SLOPE SEGMENT	LOCALITY	DAMAGED PROPERTY	DATE OF SLOPE FAILURE	SLOPE CHARACTERISTICS				DESCRIPTION OF SLOPE FAILURE				EXISTING SLOPE REPAIR METHOD AND ADEQUACY (AS OF LATE 1980)	RECOMMENDED MITIGATION METHOD (2)	SOURCE OF DATA (3)
				TYPE AND SLOPE OF SLOPE	HEIGHT OF SLOPE (IN FEET)	BENCH DRAIN	TYPE OF VEGETATION	SLOPE MATERIAL AND UNIT (PLATE 1)	TYPE AND CAUSE	AREA (LENGTH x WIDTH) (IN FEET)	ESTIMATED DEPTH (IN FEET)			
1A	1a	9300, 9310 Jefferson Blvd. Culver City	1978, 1980	Cut (1:1)	50+	None	Brush	Q1-sandstone	Rotational landslide (see remarks and text); shallow slumping (behind 9310 Jefferson Blvd.)	9300 Jefferson: about 180 wide	Scarp - 30+	Retaining walls	9300 Jefferson Blvd.: Snow pin system; remove and recompact debris; reconstruct original retaining wall.	Field observation; Aiko Geotechnical Consultants Inc., May 8, 1980; Aerial photo interpretation
	2a	9300 Jefferson Blvd. Culver City	1980 or before	Cut (1:1)		None	Brush	Q1-sandstone	Slumping due to saturation (also see "Remarks")	About 60-80 wide	Up to 6+			Field observation
	3	9350 Jefferson Blvd. Culver City	1980	70° cut at toe of 1:1 cut		None		Q1	Minor sloughing		1-2			Field observation
1B		See text					Brush		See text					Field observation; aerial photo interpretation
1C	1c	3951 Shedd Terrace Culver City	1978	Fill		None		af-fill (about 1952)	See "Remarks"			Cracking of a patio slab and structural distress occurred at the north side of this residence.	Underpinning	Lockwood-Singh & Associates, July 5, 1979
	4	6003 Wrightcrest Dr. 1919, 1923, 1945 Perran Dr. Culver City	1978, 1980	Fill cut				af-fill, about 1950	Shallow slips or slumps; settlement and creep	About 180 wide		Shallow failures occurred at all four addresses in 1978. Creep and settlement (or slumping) of the fill under the driveway at 6003 Wrightcrest Dr. has resulted in the front walkway pulling away from the house and its foundations. The entry gate to this property has tilted due to settlement or creep of its foundation materials (see photo 14).		LeRoy Crandall & Associates, February 2, 1979, April 9, 1980; Field observation
	5	3944 Wrightcrest Dr. above Perran Dr. Culver City	1978	Fill cut		None		af-fill (about 1952)	Superficial slippage	About 40+ wide		The patio deck and rear portion of the house were damaged by the slope failure.	The slope was recompact and the original loose block wall at a road cut below was replaced by a retaining wall of pre-cast concrete panels supported by caissons.	LeRoy Crandall & Associates, February 2, 1979; Field observation
1E	6	3844, 3846 Crestview Rd. 1846 Howardview Ct. Culver City	1978	Cut		None	Ivy	Q1	Superficial slump			The failure destroyed the garage at 3846 Crestview Rd. Although there have been no stability problems here since repair, the property owner was having difficulty in 1980 reestablishing vegetation (see photo 34).	The slope was reconstructed with imported fill and soil cement.	Field observation and discussion with owner.
1F		3983 Shedd Terrace (on Lauren May) 1905 Laurel Court Culver City	1978, 1980			None		af-fill (about 1952)	Retaining wall failures due to saturation	3983 Shedd Terr.: about 30 wide		In addition to the retaining wall failure at 3983 Shedd Terrace there occurred subsidence of the swimming pool. In the course of repairs in 1980 evidence was found of several previous retaining wall foundations, indicating a history of problems.	3983 Shedd Terrace: Retaining wall on caissons; drainage provisions include preventing infiltration of water from the lot pad, and especially the pool area (repairs made in 1980).	Field observation and discussion with project engineer.
1G	8	Linda Vista School	1978	Cut (1:1)		Top of slope	Ice plant	Q1	Soil slips due to saturation of steep slope		Shallow (less than 5 feet)	Plastic sheeting placed on the slope in 1980 prevented further storm damage.	See "Remarks"	Field observation
1H		See text							See text					Field observation; aerial photo interpretation

- (1) Including dates of development during which fills (af) were replaced.
(2) Recommendation by consultant listed under source of data.
(3) Names and dates refer to name of consultant preparing report and date of report.

TABLE 1c. DESCRIPTIONS OF SLOPE FAILURES IN SUB-AREA 3, THE NORTHEASTERN PART OF THE BALDWIN HILLS, BY E.Y. HSU AND S.S. TAN

TABLE X. DESCRIPTIONS OF SLOPE FAILURES IN SUB-AREA 3, THE NORTH-EASTERN PART OF THE BALDWIN HILLS, BY E.Y. HSU AND S.S. TAN															
(1) SLOPE SEGMENT	(2) LOCALITY	(3) DAMAGED PROPERTIES	(4) DATES OF SLOPE DAMAGE	(5) SLOPE CHARACTERISTICS				(6) DESCRIPTION OF SLOPE FAILURE				(7) EXISTING SLOPE REPAIR METHOD AS OF FEBRUARY 1981	(8) RECOMMENDED STABILIZATION METHOD (2)	(9) SOURCE OF DATA (3)	
				(10) SLOPE ANGLE	(11) HEIGHT OF SLOPE (IN FEET)	(12) BENCH DRAIN	(13) TYPE OF VEGETATION	(14) SLOPE MATERIAL (AND GEOLOGIC UNIT ON PLATE 1)	(15) TYPE AND CAUSE OF FAILURE	(16) SIZE (IN FEET)					
										AREA (LENGTH x WIDTH)	DEPTH OF FAILURE				
2A	51	4293 Don Carlos Dr. Tract 20871, Lot 1	1969 March 1978	1:1/2:1	100	No	Grass and shrubs	Fill (af)	Erosion and soil slips; due to improper construction of retaining wall and backfill.	15 x 70	Less than 3 (scarp 7 feet high)	Retaining wall damaged.	Engineered fill.		Geosols (1/4/79) Field observation, L.A. City file
	52	4711 to 4745 Don Miguel Dr. Tract 20870 Lots 56 to 64	Possibly 1964 1980	1:1/2:1	30-45	Yes, paved	Grass and shrubs	Fill (af)	Erosion and soil slips; cause not determined.	500 long	Max. 4	Concrete drains seriously undermined.	Engineered fill.		Foundation Engineering Company (9/66) Pacific Soils Engineering (8/23/66, 8/23/66) Field observation
	54	4765 Don Miguel Dr. Tract 20870, Lots 66 and 67	Possibly 1967 and 1973 1978, 1980	1:1/2:1	30	No	Grass and shrubs	Fill (af)	Soil slips, erosion gullies and debris flow, due to poor yard drainage.	15 x 30	2	Swimming pool damaged.	Engineered fill mixed with 5% Portland cement.		Lockwood and Singh (5/14/74, 1/13/75) Pacific Soils Engineering, (3/17/67) Field observation, L.A. City file
2B	55	4149 Don Jose Dr. Tract 20871, Lot 42	Possibly 1967 1980	1:1	61	No	Grass	Siltstone (Q1)	Soil slips and erosion; due to poor yard drainage.	18 x 130	Max. 3	Revetment system undermined by 1980 rains.	Slope was trimmed back and repaired with soil-cement fill and revetment system.		Geosols (3/7/69, 6/7/70, 5/27/70) Field observation
	56	4141 Don Jose Dr. Tract 20872, Lot 44	Possibly 1969 1980	1:1	30	No	Ivy	Siltstone (Q1)	Soil slips and erosion gullies; water flowing over top of slope.	15 x 15	at least 3 (scarp 7 feet high)	None.	Not repaired.		Foundation Engineering (6/24/69) Field observation, L.A. City file
2C	57	4563 Don Rudolph Pl.	1978	1:1/2:1	20	No	Ivy	Silt and clayey sand (af)	Soil slip; cause not determined.	30 x 30	2 (scarp 2-4 feet high)	Separation of house and garage, undermining of retaining wall and distressed block wall and patio.	Pipe-and-board revetment system.		Lockwood and Singh (10/6/78) Field observation, L.A. City file
2D	58	4547 Don Miguel Dr. Tract 17455, Lot 67	February and March 1978	1:1/2:1	58	No	Ice plant	Fill (af)	Erosion gullies (photo 21); cause not determined.	55 x 25	2		Not repaired.	Consultant suggested repair of the slope with keyed fill, paved bench drains, concrete cover in swales and retaining wall at top.	Pacific Soils Engineering (11/27/78) Field observation, L.A. City file
	59	4219 Don Alegre Pl.	1965 1978	1:1/2:1	40	No	Ground cover, shrubs and trees	Fill (af)	Shallow slump, (photo 21) due to excessive moisture.	30 x 40	2-3	None.	Not repaired.	Consultant recommended revetment system and engineered fill with a drainage bench.	Converse-Davis-Dixon (4/7/80) Field observation, L.A. City file
2E	60	4472 Don Miguel Dr.	1978	1:1/2:1	80-100	No	Ivy	Siltstone (Q1)	Soil slip and erosion; due to poor slope drainage control.	30 x 10	3	Cracking and bulging of retaining wall was caused by a lack of proper subsurface drainage.	Not repaired.	Consultant recommended that slope be repaired with engineered fill.	Soils International (10/4/78) Field observation, L.A. City file
2F	61	4224 Don Alegre Pl. 4217 and 4209 Hillcrest Dr.	1980	1:1/2:1	30	No	Ice plant	Fill (af)	Slumps and debris flow; (photo 22) probably due to improperly constructed fill, improper discharge of water over top of slope, and lack of slope drainage control.	50 wide	Scarp 20 feet high	Debris flow travelled for about 250 feet and seriously damaged house at 4217 Hillcrest Dr.; debris 10 feet thick accumulated.	Engineered fill.		Field observation, L.A. City file
2H	62	4256 Don Ortega Pl. Tract 17451, Lot 14	February and March 1978	1:1/2:1	35	No	Ground cover, shrubs and trees	Fill (af) Siltstone (Q1)	Soil slips; cause not determined.			South wing of house distressed.	Unknown.	Consultant recommended underpinning of house.	Lockwood and Singh (7/17/79) Field observation
	63	4435 Don Miguel Dr.	1978	1:1	60	No	Ivy	Fill (af) Clayey sandstone (Q1)	Erosion; cause not determined.	25 x 35	Less than 3	None.	Engineered fill.		Soils International (2/22/79) Field observation, L.A. City file
2I	64	4215 Don Olafio Dr. Tract 14664, Lot 55	1978 (?) 1980	1:1	55	No	Grass	Fill (af)	Erosion and soil slips; cause not determined.	30 x 30	Max. 5	Concrete patio and wooden fence.	Not repaired.		Field observation L.A. City file
	65	4121, 4127 Don Olafio Dr., Tract 14664, Lot 60, 61	1969	1:1/2:1	30	No	Ivy	Silty sand (af)	Soil slips and erosion gullies; cause not determined.			Concrete steps broken and displaced.	Engineered fill.		Maurerth, Hovess, Lockwood Assoc. (8/21/69, Feb/71, 5/13/71) Field observation
	66	4101 Don Olafio Dr. Tract 14664, Lot 64	February 1962	1:1 to 1:1/2:1	40	No	Ivy	Fill (af)	Shallow slumps; cause not determined.			Retaining wall cracked.	Engineered fill.		R.G. Osborne Laboratories, Inc. (7/12/62, 6/29/67, 8/28/67)
2J (1-3)	67	4100 Don Ibarra Pl. Tract 17451, Lot 53	1969 1978	1:1/2:1	60	No	Combined ground cover of shrubs and trees	Clayey sand (Q1)	Shallow slump; cause not determined.	30 x 25	2	Patio cracked.	Pipe and board revetment system.		Ralph Stone and Co. (7/26/78) Field observation, L.A. City file
2K	68	4275 Don Mariano Dr. Tract 17451, Lot 53	February and March 1978	1:1/2:1 to 2:1	30-40	No	Ivy, shrubs and trees	Silty sand (af)	Erosion, and shallow slump; cause not determined.		Max. 3 (Scarp 2-5 feet high)	Wood revetment system destroyed; block wall at the top of slope distressed.	Construction of block wall at the top of slope and engineered soil- cement fill on slope.		Lockwood and Singh (5/2/78, 12/15/78) Field observation, L.A. City file
	69	4241 Don Mariano Dr. Tract 16279, Lot 5	End of 1976	1:1/2:1	100	No	Ivy	Fill (af)	Slump; due to broken irrigation line.		Up to 12 (reportedly 300 cubic yards)	None.	Engineered fill.		Kovacs and Byet (4/15/77)
2L	70	4260 Don Mariano Dr. Tract 16404, Lot 68	1968	1:1/2:1	About 25-30	No	Ivy	Fill (af)	Settlement and downward movement of fill slope (photo 23).			Rear side of house cracked.	Unknown.	Emplacement of caissons to strengthen foundation was recommended by consultant.	D.R. Warren Co. (10/11/68)

TABLE 30. DESCRIPTIONS OF SLOPE FAILURES IN SUB-AREA 4, THE NORTH-CENTRAL PART OF THE BALDWIN HILLS By J.A. Tien (cont.)

TABLE NO. DESCRIPTIONS OF SLOPE FAILURES IN SUB-AREA 1, THE NORTH-CENTRAL PART OF THE BALDWIN HILLS By J.A. Treiman															
LOCALITY	LOCALITY	AFFECTED PARCELS	DATE OF DAMAGE	PHYSICAL CHARACTERISTICS				DESCRIPTION OF SLOPE FAILURE				EXISTING SLOPE REPAIR METHODS AND ADEQUACY	RECOMMENDED MITIGATION METHODS (3)	SOURCE OF DATA	
				TYPE AND AREA OF SLOPE	HEIGHT OF SLOPE IN FEET	BENCH MARK	TYPE OF VEGETATION	SLOPE MATERIAL AND UNIT (PLATE 11 (1))	TYPE AND AREA	SIZE					REMARKS
										AREA (LENGTH x WIDTH) (IN FEET)	ESTIMATED DEPTH OF FAILURE (IN FEET) (2)				
1	Between Brynmore Dr. and Ridge Dr.				10-15 ft			af-fill; Qc	No damage reported or observed			No damage was recorded. Many small retaining walls.		Field observation; records search	
2	4751, 4757, 4761, 4765, Aladdin St. 4751, 4757, 4761, 4765, Aladdin St.	1978, 1980	Fill (1:1 to 1:1.5)	10-15 ft		Ivy Daisies	af-fill (1950) Qc	Slumping in 1978 due to saturation, erosion and soil slips, creep and failure of revetment in 1980 due to runoff and saturation.	4-7	Dense ivy growth adjacent to slopes that failed is probably similar to former growth on slopes that failed	Batter board revetment failing locally, daisies planted after 1978 rains were not well established as of 1980; slough walls at toe of slope appear to be adequate at present.	Retaining walls, revetment and trim slope to 2:1 or 1 1/2:1 buttress fill (Soils International, 1979 - L.A. City tract files - Tract 14674)	Field observation; L.A. City records		
3	4761, 4765, 4769, Aladdin St.	1978	Fill (1:1 to 1:1.5)	10-15 ft		Ivy trees	af-fill (1950) Qc	Retaining wall failure. Slump and erosion due to saturation of uncompacted fill.	About 7	Uncompacted fill was placed on the slope during tract grading. Debris from the failure described may have been responsible for minor damage reported down-slope at 4624 and 4630 Aladdin St.	Retaining wall, no problems with it reported or observed.	Retaining wall on caissons recommended but not possible; retaining wall constructed without caissons considered remedial (Lockwood-Singh & Associates, 1979 - L.A. City tract files - Tract 14674)	Field observation; L.A. City records		
4	4624, 4630, 4634, 4638, 4642, 4646, 4650, 4654, 4658, 4662, 4666, 4670, 4674, 4678, 4682, 4686, 4690, 4694, 4698, 4702, 4706, 4710, 4714, 4718, 4722, 4726, 4730, 4734, 4738, 4742, 4746, 4750, 4754, 4758, 4762, 4766, 4770, 4774, 4778, 4782, 4786, 4790, 4794, 4798, 4802, 4806, 4810, 4814, 4818, 4822, 4826, 4830, 4834, 4838, 4842, 4846, 4850, 4854, 4858, 4862, 4866, 4870, 4874, 4878, 4882, 4886, 4890, 4894, 4898, 4902, 4906, 4910, 4914, 4918, 4922, 4926, 4930, 4934, 4938, 4942, 4946, 4950, 4954, 4958, 4962, 4966, 4970, 4974, 4978, 4982, 4986, 4990, 4994, 4998, 5002, 5006, 5010, 5014, 5018, 5022, 5026, 5030, 5034, 5038, 5042, 5046, 5050, 5054, 5058, 5062, 5066, 5070, 5074, 5078, 5082, 5086, 5090, 5094, 5098, 5102, 5106, 5110, 5114, 5118, 5122, 5126, 5130, 5134, 5138, 5142, 5146, 5150, 5154, 5158, 5162, 5166, 5170, 5174, 5178, 5182, 5186, 5190, 5194, 5198, 5202, 5206, 5210, 5214, 5218, 5222, 5226, 5230, 5234, 5238, 5242, 5246, 5250, 5254, 5258, 5262, 5266, 5270, 5274, 5278, 5282, 5286, 5290, 5294, 5298, 5302, 5306, 5310, 5314, 5318, 5322, 5326, 5330, 5334, 5338, 5342, 5346, 5350, 5354, 5358, 5362, 5366, 5370, 5374, 5378, 5382, 5386, 5390, 5394, 5398, 5402, 5406, 5410, 5414, 5418, 5422, 5426, 5430, 5434, 5438, 5442, 5446, 5450, 5454, 5458, 5462, 5466, 5470, 5474, 5478, 5482, 5486, 5490, 5494, 5498, 5502, 5506, 5510, 5514, 5518, 5522, 5526, 5530, 5534, 5538, 5542, 5546, 5550, 5554, 5558, 5562, 5566, 5570, 5574, 5578, 5582, 5586, 5590, 5594, 5598, 5602, 5606, 5610, 5614, 5618, 5622, 5626, 5630, 5634, 5638, 5642, 5646, 5650, 5654, 5658, 5662, 5666, 5670, 5674, 5678, 5682, 5686, 5690, 5694, 5698, 5702, 5706, 5710, 5714, 5718, 5722, 5726, 5730, 5734, 5738, 5742, 5746, 5750, 5754, 5758, 5762, 5766, 5770, 5774, 5778, 5782, 5786, 5790, 5794, 5798, 5802, 5806, 5810, 5814, 5818, 5822, 5826, 5830, 5834, 5838, 5842, 5846, 5850, 5854, 5858, 5862, 5866, 5870, 5874, 5878, 5882, 5886, 5890, 5894, 5898, 5902, 5906, 5910, 5914, 5918, 5922, 5926, 5930, 5934, 5938, 5942, 5946, 5950, 5954, 5958, 5962, 5966, 5970, 5974, 5978, 5982, 5986, 5990, 5994, 5998, 6002, 6006, 6010, 6014, 6018, 6022, 6026, 6030, 6034, 6038, 6042, 6046, 6050, 6054, 6058, 6062, 6066, 6070, 6074, 6078, 6082, 6086, 6090, 6094, 6098, 6102, 6106, 6110, 6114, 6118, 6122, 6126, 6130, 6134, 6138, 6142, 6146, 6150, 6154, 6158, 6162, 6166, 6170, 6174, 6178, 6182, 6186, 6190, 6194, 6198, 6202, 6206, 6210, 6214, 6218, 6222, 6226, 6230, 6234, 6238, 6242, 6246, 6250, 6254, 6258, 6262, 6266, 6270, 6274, 6278, 6282, 6286, 6290, 6294, 6298, 6302, 6306, 6310, 6314, 6318, 6322, 6326, 6330, 6334, 6338, 6342, 6346, 6350, 6354, 6358, 6362, 6366, 6370, 6374, 6378, 6382, 6386, 6390, 6394, 6398, 6402, 6406, 6410, 6414, 6418, 6422, 6426, 6430, 6434, 6438, 6442, 6446, 6450, 6454, 6458, 6462, 6466, 6470, 6474, 6478, 6482, 6486, 6490, 6494, 6498, 6502, 6506, 6510, 6514, 6518, 6522, 6526, 6530, 6534, 6538, 6542, 6546, 6550, 6554, 6558, 6562, 6566, 6570, 6574, 6578, 6582, 6586, 6590, 6594, 6598, 6602, 6606, 6610, 6614, 6618, 6622, 6626, 6630, 6634, 6638, 6642, 6646, 6650, 6654, 6658, 6662, 6666, 6670, 6674, 6678, 6682, 6686, 6690, 6694, 6698, 6702, 6706, 6710, 6714, 6718, 6722, 6726, 6730, 6734, 6738, 6742, 6746, 6750, 6754, 6758, 6762, 6766, 6770, 6774, 6778, 6782, 6786, 6790, 6794, 6798, 6802, 6806, 6810, 6814, 6818, 6822, 6826, 6830, 6834, 6838, 6842, 6846, 6850, 6854, 6858, 6862, 6866, 6870, 6874, 6878, 6882, 6886, 6890, 6894, 6898, 6902, 6906, 6910, 6914, 6918, 6922, 6926, 6930, 6934, 6938, 6942, 6946, 6950, 6954, 6958, 6962, 6966, 6970, 6974, 6978, 6982, 6986, 6990, 6994, 6998, 7002, 7006, 7010, 7014, 7018, 7022, 7026, 7030, 7034, 7038, 7042, 7046, 7050, 7054, 7058, 7062, 7066, 7070, 7074, 7078, 7082, 7086, 7090, 7094, 7098, 7102, 7106, 7110, 7114, 7118, 7122, 7126, 7130, 7134, 7138, 7142, 7146, 7150, 7154, 7158, 7162, 7166, 7170, 7174, 7178, 7182, 7186, 7190, 7194, 7198, 7202, 7206, 7210, 7214, 7218, 7222, 7226, 7230, 7234, 7238, 7242, 7246, 7250, 7254, 7258, 7262, 7266, 7270, 7274, 7278, 7282, 7286, 7290, 7294, 7298, 7302, 7306, 7310, 7314, 7318, 7322, 7326, 7330, 7334, 7338, 7342, 7346, 7350, 7354, 7358, 7362, 7366, 7370, 7374, 7378, 7382, 7386, 7390, 7394, 7398, 7402, 7406, 7410, 7414, 7418, 7422, 7426, 7430, 7434, 7438, 7442, 7446, 7450, 7454, 7458, 7462, 7466, 7470, 7474, 7478, 7482, 7486, 7490, 7494, 7498, 7502, 7506, 7510, 7514, 7518, 7522, 7526, 7530, 7534, 7538, 7542, 7546, 7550, 7554, 7558, 7562, 7566, 7570, 7574, 7578, 7582, 7586, 7590, 7594, 7598, 7602, 7606, 7610, 7614, 7618, 7622, 7626, 7630, 7634, 7638, 7642, 7646, 7650, 7654, 7658, 7662, 7666, 7670, 7674, 7678, 7682, 7686, 7690, 7694, 7698, 7702, 7706, 7710, 7714, 7718, 7722, 7726, 7730, 7734, 7738, 7742, 7746, 7750, 7754, 7758, 7762, 7766, 7770, 7774, 7778, 7782, 7786, 7790, 7794, 7798, 7802, 7806, 7810, 7814, 7818, 7822, 7826, 7830, 7834, 7838, 7842, 7846, 7850, 7854, 7858, 7862, 7866, 7870, 7874, 7878, 7882, 7886, 7890, 7894, 7898, 7902, 7906, 7910, 7914, 7918, 7922, 7926, 7930, 7934, 7938, 7942, 7946, 7950, 7954, 7958, 7962, 7966, 7970, 7974, 7978, 7982, 7986, 7990, 7994, 7998, 8002, 8006, 8010, 8014, 8018, 8022, 8026, 8030, 8034, 8038, 8042, 8046, 8050, 8054, 8058, 8062, 8066, 8070, 8074, 8078, 8082, 8086, 8090, 8094, 8098, 8102, 8106, 8110, 8114, 8118, 8122, 8126, 8130, 8134, 8138, 8142, 8146, 8150, 8154, 8158, 8162, 8166, 8170, 8174, 8178, 8182, 8186, 8190, 8194, 8198, 8202, 8206, 8210, 8214, 8218, 8222, 8226, 8230, 8234, 8238, 8242, 8246, 8250, 8254, 8258, 8262, 8266, 8270, 8274, 8278, 8282, 8286, 8290, 8294, 8298, 8302, 8306, 8310, 8314, 8318, 8322, 8326, 8330, 8334, 8338, 8342, 8346, 8350, 8354, 8358, 8362, 8366, 8370, 8374, 8378, 8382, 8386, 8390, 8394, 8398, 8402, 8406, 8410, 8414, 8418, 8422, 8426, 8430, 8434, 8438, 8442, 8446, 8450, 8454, 8458, 8462, 8466, 8470, 8474, 8478, 8482, 8486, 8490, 8494, 8498, 8502, 8506, 8510, 8514, 8518, 8522, 8526, 8530, 8534, 8538, 8542, 8546, 8550, 8554, 8558, 8562, 8566, 8570, 8574, 8578, 8582, 8586, 8590, 8594, 8598, 8602, 8606, 8610, 8614, 8618, 8622, 8626, 8630, 8634, 8638, 8642, 8646, 8650, 8654, 8658, 8662, 8666, 8670, 8674, 8678, 8682, 8686, 8690, 8694, 8698, 8702, 8706, 8710, 8714, 8718, 8722, 8726, 8730, 8734, 8738, 8742, 8746, 8750, 8754, 8758, 8762, 8766, 8770, 8774, 8778, 8782, 8786, 8790, 8794, 8798, 8802, 8806, 8810, 8814, 8818, 8822, 8826, 8830, 8834, 8838, 8842, 8846, 8850, 8854, 8858, 8862, 8866, 8870, 8874, 8878, 8882, 8886, 8890, 8894, 8898, 8902, 8906, 8910, 8914, 8918, 8922, 8926, 8930, 8934, 8938, 8942, 8946, 8950, 8954, 8958, 8962, 8966, 8970, 8974, 8978, 8982, 8986, 8990, 8994, 8998, 9002, 9006, 9010, 9014, 9018, 9022, 9026, 9030, 9034, 9038, 9042, 9046, 9050, 9054, 9058, 9062, 9066, 9070, 9074, 9078, 9082, 9086, 9090, 9094, 9098, 9102, 9106, 9110, 9114, 9118, 9122, 9126, 9130, 9134, 9138, 9142, 9146, 9150, 9154, 9158, 9162, 9166, 9170, 9174, 9178, 9182, 9186, 9190, 9194, 9198, 9202, 9206, 9210, 9214, 9218, 9222, 9226, 9230, 9234, 9238, 9242, 9246, 9250, 9254, 9258, 9262, 9266, 9270, 9274, 9278, 9282, 9286, 9290, 9294, 9298, 9302, 9306, 9310, 9314, 9318, 9322, 9326, 9330, 9334, 9338, 9342, 9346, 9350, 9354, 9358, 9362, 9366, 9370, 9374, 9378, 9382, 9386, 9390, 9394, 9398, 9402, 9406, 9410, 9414, 9418, 9422, 9426, 9430, 9434, 9438, 9442, 9446, 9450, 9454, 9458, 9462, 9466, 9470, 9474, 9478, 9482, 9486, 9490, 9494, 9498, 9502, 9506, 9510, 9514, 9518, 9522, 9526, 9530, 9534, 9538, 9542, 9546, 9550, 9554, 9558, 9562, 9566, 9570, 9574, 9578, 9582, 9586, 9590, 9594, 9598, 9602, 9606, 9610, 9614, 9618, 9622, 9626, 9630, 9634, 9638, 9642, 9646, 9650, 9654, 9658, 9662, 9666, 9670, 9674, 9678, 9682, 9686, 9690, 9694, 9698, 9702, 9706, 9710, 9714, 9718, 9722, 9726, 9730, 9734, 9738, 9742, 9746, 9750, 9754, 9758, 9762, 9766, 9770, 9774, 9778, 9782, 9786, 9790, 9794, 9798, 9802, 9806, 9810, 9814, 9818, 9822, 9826, 9830, 9834, 9838, 9842, 9846, 9850, 9854, 9858, 9862, 9866, 9870, 9874, 9878, 9882, 9886, 9890, 9894, 9898, 9902, 9906, 9910, 9914, 9918, 9922, 9926, 9930, 9934, 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10518, 10522, 10526, 10530, 10534, 10538, 10542, 10546, 10550, 10554, 10558, 10562, 10566, 10570, 10574, 10578, 10582, 10586, 10590, 10594, 10598, 10602, 10606, 10610, 10614, 10618, 10622, 10626, 10630, 10634, 10638, 10642, 10646, 10650, 10654, 10658, 10662, 10666, 10670, 10674, 10678, 10682, 10686, 10690, 10694, 10698, 10702, 10706, 10710, 10714, 10718, 10722, 10726, 10730, 10734, 10738, 10742, 10746, 10750, 10754, 10758, 10762, 10766, 10770, 10774, 10778, 10782, 10786, 10790, 10794, 10798, 10802, 10806, 10810, 10814, 10818, 10822, 10826, 10830, 10834, 10838, 10842, 10846, 10850, 10854, 10858, 10862, 10866, 10870, 10874, 10878, 10882, 10886, 10890, 10894, 10898, 10902, 10906, 10910, 10914, 10918, 10922, 10926, 10930, 10934, 10938, 10942, 10946, 10950, 10954, 10958, 10962, 10966, 10970, 10974, 10978, 10982, 10986, 10990, 10994, 10998, 11002, 11006, 11010, 11014, 11018, 11022, 11026, 11030, 11034, 11038, 11042, 11046, 11050, 11054, 11058, 11062, 11066, 11070, 11074, 11078, 11082, 11086, 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S. 17451	71	4447 Don Rosa Pl. Tract 17451, Lot 106	1978-1979	2.1 to 1 (2:1)	25 (fill slope)	No	Ice plant	Fill (sf)	Shallow slump; cause not determined (photo 25).	10 x 40	None	Engineered fill.	Field observation (April/80), L.A. City file	
	72	4447 Don Rosa Pl. Tract 17451, Lot 107	February and March 1978	1.1 to 1 (2:1)	75	No	Ice plant	Silty sand and clay (sf) Sandstone (Q1)	Soil slip and erosion gullies (photos 24 and 25); cause not determined.	1-3	None	Not required.	Consultant recommended filling of gullies, installation of wire fences to hold back debris at toe of slope and establishment of a rodent abatement program.	Soils International (2/9/79) Geolabs (12/19/78) Field observation, L.A. City file
	73	4447 Don Rosa Pl. Tract 17451, Lot 108	February and March 1978	1.1 to 1 (2:1)	75	No	Ice plant and shrubs	Fill (sf), Siltstone (Q1)	Erosion, debris flow and soil slips (photos 24 and 29); cause not determined		Max. 2	As of April, 1980, debris was piled up in the western portion of carport of the apartment building at Don Lomas Dr. Rear wall of 4324 Don Luis Dr. was cracked.	Block wall at top of slope, wood-pipe revetment system on the slope, slough wall at the toe and middle of slope; engineered fill and gunite in drainage swale.	Lockwood and Singh (12/19/78) Field observation, L.A. City file
	74	4447 Don Rosa Pl. Tract 17451, Lot 109	March 4, 1978	1.1 to 1 (2:1)	95	No	Ice plant	Sandy clay to Siltstone (Q1)	Slump and debris flow, cause not determined.		Max. 3	Debris flow broke through the rear wall of apartment building and almost completely filled the living room of one unit.	Slope regraded and terraced; subdrain installed.	Geolabs (11/80) Field observation, L.A. City file
	75	4447 Don Rosa Pl. Tract 17451, Lot 110	February and March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Mainly in fill (sf) Also in siltstone (Q1)	Soil slips; cause not determined	15 x 30	Scarp 1-4 feet high	Revetment system distressed.	Engineered fill and retaining wall on slope.	Lockwood and Singh (2/2/79, 11/26/79) Field observation, L.A. City file
S. 17451	76	4447 Don Rosa Pl. Tract 17451, Lot 111	March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Sand and gravel (Q1)	Shallow slump and erosion (photo 27); due to poor yard drainage	50 x 174	Max. 5 (Scarp 7 feet high)	Failure of slope exposed footing of wood fence at the base of the slope.	Not repaired.	Field observation, L.A. City file
	77	4447 Don Rosa Pl. Tract 17451, Lot 112	March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Siltstone (Q1)	Soil slips and erosion probably due to improper, or lack of, subsurface drainage system at the base of fill.		Scarp up to 3 feet high	Pavement in public park damaged.	Not repaired.	Field observation, L.A. City file
	78	4447 Don Rosa Pl. Tract 17451, Lot 113	March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Sand and gravel (Q1) Also fill (sf)	Erosion gullies in up and at		Scarp up to 10-15 feet high	Headward erosion caused minor failures in fills.	Not repaired.	Field observation, L.A. City file
S. 17451	79	4447 Don Rosa Pl. Tract 17451, Lot 114	March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Siltstone (Q1)	Soil slips; due to lack of surface and/or subsurface drainage which caused excessive flow of water over the slope. Several points of seepage were observed at the base of fill slopes.		Scarps up to 6 feet high	Continuing erosion may endanger properties on north side of Enero Drive.	Not repaired.	Field observation, L.A. City file
	80	4447 Don Rosa Pl. Tract 17451, Lot 115	March 1978	1.1 to 1 (2:1)	85	No	Ice plant	Siltstone (Q1)	Slump or soil slip and debris flow Cause not determined.		Head scarp up to 7 feet high	Concrete deck and swimming pool undermined.	Not repaired.	Field observation, L.A. City file

The following slope segments not listed hereon, are described only in the text: 1-23, 1-24, 1-25, 1-26, 1-27, 1-28, 1-29, 1-30, 1-31, 1-32, 1-33, 1-34, 1-35, 1-36, 1-37, 1-38, 1-39, 1-40, 1-41, 1-42, 1-43, 1-44, 1-45, 1-46, 1-47, 1-48, 1-49, 1-50, 1-51, 1-52, 1-53, 1-54, 1-55, 1-56, 1-57, 1-58, 1-59, 1-60, 1-61, 1-62, 1-63, 1-64, 1-65, 1-66, 1-67, 1-68, 1-69, 1-70, 1-71, 1-72, 1-73, 1-74, 1-75, 1-76, 1-77, 1-78, 1-79, 1-80, 1-81, 1-82, 1-83, 1-84, 1-85, 1-86, 1-87, 1-88, 1-89, 1-90, 1-91, 1-92, 1-93, 1-94, 1-95, 1-96, 1-97, 1-98, 1-99, 1-100, 1-101, 1-102, 1-103, 1-104, 1-105, 1-106, 1-107, 1-108, 1-109, 1-110, 1-111, 1-112, 1-113, 1-114, 1-115, 1-116, 1-117, 1-118, 1-119, 1-120, 1-121, 1-122, 1-123, 1-124, 1-125, 1-126, 1-127, 1-128, 1-129, 1-130, 1-131, 1-132, 1-133, 1-134, 1-135, 1-136, 1-137, 1-138, 1-139, 1-140, 1-141, 1-142, 1-143, 1-144, 1-145, 1-146, 1-147, 1-148, 1-149, 1-150, 1-151, 1-152, 1-153, 1-154, 1-155, 1-156, 1-157, 1-158, 1-159, 1-160, 1-161, 1-162, 1-163, 1-164, 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4 Including dates of development during which tillis (af) were employed.
2 Includes possible depth of potential future slope failures.
3 Recommendations by consultant referenced.

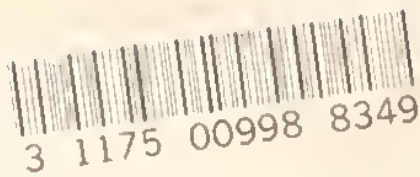
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